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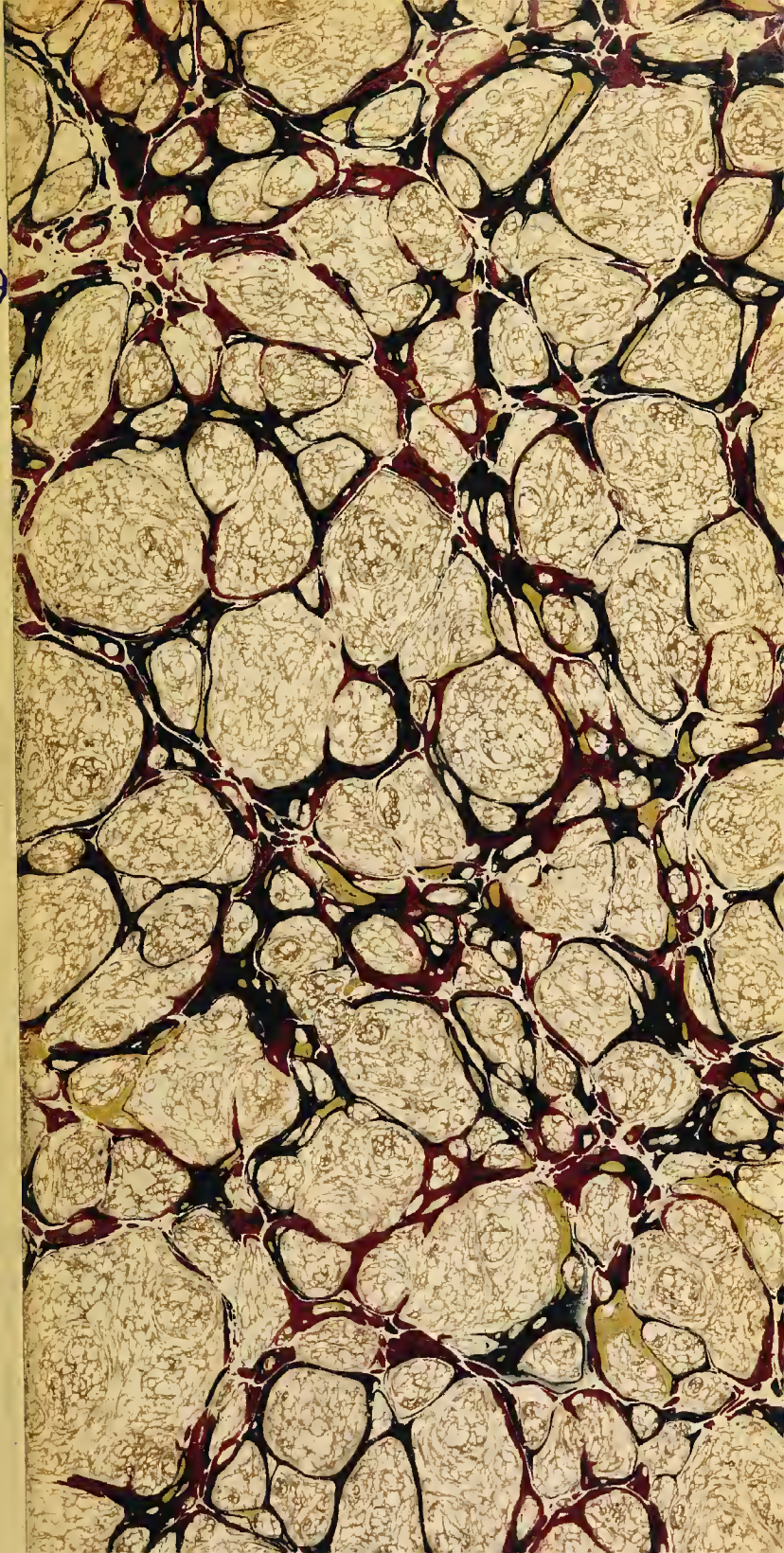

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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE

GEOLOGY

OF THE

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INCLUDING BOSTON AND HUNSTANTON.

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AND

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PREFACE.

THE districts described in this volume are contained in Sheet 69 (Old Series) of the one-inch Geological Survey Map of England and Wales. They embrace The Wash and the tracts of Lincolnshire and West Norfolk which surround that inlet of the sea. On the south and west lies the great plain of the Fenland, while to the east the ground undulates as a wide plateau, no part of which reaches 300 feet in height.

The western part of the region was chiefly surveyed by MR. S. B. J. SKERTCHLY and was described by him in a general Memoir on the Fenland (1877). The eastern or Norfolk portion, consisting of Cretaceous rocks, partially concealed under deposits of sand, gravel, and boulder-clay, was mapped by MESSRS. W. WHITAKER, H. B. WOODWARD, A. C. G. CAMERON, C. REID, G. BARROW, and S. B. J. SKERTCHLY.

The present Memoir was entrusted to the editorship of MR. WHITAKER, and on his retirement from the Survey it was completed by MR. JUKES-BROWNE. For such parts of the district of the Fenland and The Wash as are included in Sheet 69 the descriptions given in MR. SKERTCHLY'S Memoir, just referred to, have been reprinted in the following pages. The eastern district is described by the various officers who took part in the Survey, and whose several contributions are marked by their initials. MR. WILLIAM HILL rendered important service to the Geological Survey by making special examinations of the zones and lithological subdivisions of the Chalk, and supplying much valuable information in regard thereto.

The geology of the country illustrated by the Map and Memoir possesses considerable interest, but the well-known Red Chalk of Hunstanton is no doubt its distinguishing feature. As far back as 1816 this band of rock was noticed by WILLIAM SMITH. Among the later observers reference may be made to R. C. TAYLOR, SEDGWICK, C. B. ROSE, The REV. T. WILTSHIRE, and PROFESSOR H. G. SEELEY. The age and relations of the Red Chalk were fully discussed by MR.

WHITAKER in 1883, and were established by MESSRS. JUKES-BROWNE and W. HILL in 1887.

Regarding the Lower Greensand, our information, originally derived from the local researches of ROSE, followed by those of FITTON, was made much more complete and accurate by MR. J. J. H. TEALL in his Sedgwick Prize Essay for 1873. Quite recently some important additions to our knowledge of this subject have been made by MR. G. W. LAMPLUGH in the course of his researches in connection with the Geological Survey Memoir on the Lower Cretaceous rocks.

The Chalk, though it occupies most of the eastern district, forms no prominent features like the Downs of the counties to the south. It has been greatly planed down, and is likewise covered with wide sheets of boulder-clay and gravel. The boulder-clay stretches also beneath the Fenland, in some parts of which it attains a great thickness.

ARCH. GEIKIE,

Director-General.

Geological Survey Office,

28, *Jermyn Street, London, S.W.,*

10*th October*, 1898.

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H. B. WOODWARD, 67, 70, 71, 74-77, 82, 83, 86, 94, 100, 112.

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GEOLOGY OF THE BORDERS OF THE WASH.

CHAPTER I. INTRODUCTION.

AREA.

The district represented in Sheet 69 of the Geological Survey (Old Ordnance) map consists of part of south-east *Lincolnshire* with the towns of Boston, Holbeach, Sutton St. Mary, and Wainfleet, besides a number of Fenland villages, sometimes closely clustered, and the north-western corner of *Norfolk*, with the towns of Burnham and Castle Rising, the sea-side resort of Hunstanton, and a number of villages, some of which are large, as Dersingham, Docking, Heacham, and Snettisham.

The deep bay of The Wash cuts through the central part of this district, almost to its southern border, and practically divides the two counties. Moreover, the rising ground is wholly on the eastern side of the bay, which therefore also practically separates two different areas of land.

RIVERS.

As the district is largely sea-bord, The Wash being part of the sea, and not really river-estuary (though many streams flow into it), it contains of course no great length of river-valley: indeed, the Lincolnshire part, which is almost wholly Fenland, has no such thing as a valley; but in it are the outfalls of the following rivers:—

The *Nene*, on the south, eastward of Sutton.

The *Welland* at Fossdyke, and the *Witham* at Boston, on the west.

The *Steeping*, on the north, at Wainfleet Harbour.

In Norfolk is the mouth of the *Ouse*, a river which has a very large drainage-area, whilst the following three streams flow westward into The Wash:—

The *Babingley River*, which usually rises in the Middle Chalk about a mile above Flitcham, and flows in a fairly direct westerly course for some seven miles to near Wolferton, with small tributaries from Congham, on the south, and from Appleton and West Newton, on the north.

The stream rising from near the base of the Chalk at Shernborne, which, reinforced from the Lower Greensand, finds its way into salt water at Wolferton Creek.

The stream rising in various parts of the Chalk above

Sedgford and having its exit near Heacham, with a tributary from near Ringstead, on the north.

On the northern coast the stream from South Creake flows northward to the sea at Burnham Harbour; whilst in other parts there are only tiny streamlets.

At the Rudhams, between Syderstone and Tatterset, and a few miles to the south, are the head waters of the Wensum, an eastern river that flows hence right across the country. The drainage of the south-eastern corner of the district is therefore distinctly separate from that of the rest, the latter belonging to the system of the Ancient Ouse, while the former belongs to that of the Ancient Thames, those names being used for the former extension of the two rivers, before England became an island, or at all events was so widely severed from Europe as now. At one time probably the Ouse itself was a tributary of the Thames. The great cutting back of the land in eastern England has resulted in forming a multitude of separate drainage-areas of comparatively small size (and many very small) where once all formed parts of a dominant system, with which they have now no apparent connection.

Geological Formations and their Range.

The various beds noted in the right column of the following Table are those which have been mapped as occurring at the surface in the district. Between the Cretaceous beds and the Drift there is, of course, a great gap, no trace of any Pliocene bed having been found, whilst the great Eocene series does not reach into western Norfolk, being, in that county, confined to the eastern margin. Here, too, the higher part of the Upper Chalk has also been lost by erosion.

Recent ...	Coast Deposits ...	Blown Sand. Shingle.
	... ...	Alluvium, including Peat and Fen Silt, which are separately mapped in the Fenland.
Post-Glacial Drift	River and Valley Drift	Loam and Marl. Gravel.
	... ...	Marine Gravel (Hunstanton).
Glacial Drift		Gravel and Sand, including Eskers (age sometimes doubtful: some beds above, some below Boulder Clay). Boulder Clay, perhaps of two ages. Brick-earth or Loam.
Upper Cretaceous	Chalk	Upper and Middle Chalk. Lower Chalk.
	... .	Red Chalk (a line only on the map). Gault Marl or Clay.
Lower Cretaceous.	Lower Greensand (undivided on the south) ...	Carstone. Snettisham Beds. Sandringham Sands.
Upper Jurassic ...	... ...	Kimeridge Clay.

Besides the above, clays of Corallian age, and then *Oxford Clay*, probably occur beneath the Kimeridge Clay, under the

Alluvium and Drift of Lincolnshire, and reach eastward at increasing depth underground in Norfolk, though how far we know not. Nor do we know what formation next underlies the Oxford Clay.

The *Kimeridge Clay* underlies the Alluvium and Drift of the Fenland, though never coming to the surface. On the eastern side of The Wash it also holds a like position for a short distance from our southern margin, the Lower Greensand probably coming on over it in the marshes somewhere near Wolferton, from the slight northerly fall of the beds.

At the surface this clay was seen only in very small outcrops between South and North Wootton, which, being without sections, need no further notice: it is the spread of gravel here that hides this formation. Of the underground extension of this clay eastward, beneath the Cretaceous beds, we know next to nothing; presumably it was touched below the Lower Greensand in the well at Holkham Hall* (in Sheet 68, north-west of our district), but it is possible that the clay touched at the bottom of the boring (743 or 752 feet) may be a bed in the Lower Greensand. Eastward of this there is no boring in Norfolk that has passed through the Cretaceous beds.

With the above slight exception, the Cretaceous beds, with their coverings of Drift and of Alluvium, form the part of our district east of The Wash. The *Lower Greensand* has an outcrop some four miles or more broad on the south, but narrowing northward, on account of the slight fall in the beds in that direction, until lost below the sea at the far end of Hunstanton cliff; and thus it forms, with sundry masses of Drift, the eastern border of The Wash. The *Gault*, as a clayey bed, occurs at the surface as a narrow band on the south, and this, from the thinning of the formation, gradually gets narrower northward, until it disappears at Sandringham, where its place is taken by the Red Chalk, which is too thin for its outcrop to be shown by more than a line on the map. All eastward of this is *Chalk*, more or less bare at first, but soon capped by isolated patches of Drift, and then, further eastward, by a more or less continuous sheet, from beneath which the Chalk comes to the surface almost wholly in valleys only.

Of the underground extension of the Lower Greensand we know that it must pass beyond Holkham, where a thickness of 50 or 70 feet was found in the deep boring; and we may therefore conclude that the formation occurs throughout our district, eastward from the outcrop, though probably thinning somewhat in that direction.

The Gault, or the Red Chalk, may be safely taken as continuous underground, eastward from their outcrop; and the latter seems to reach to beyond Holkham, judging by the well-section above alluded to, which gives it a thickness of eight feet, the underlying blue Gault being 10 feet thick.

---

* See "The Geology of the Country around Fakenham," &c., p. 51 (1884).

The Glacial Drift occurs irregularly over the formations already noted, and at all levels, underlying the Fens and covering the plateau of the Cretaceous beds, as well as running down some of the slopes, and to the bottom of some of the valleys. It is Boulder Clay almost wholly that reaches the lowest levels, the rarer gravels and sand being mostly confined to higher ground.

The later gravels of the River or Valley Drift are confined to the bottoms and lower slopes of the valleys, for we have here none of the higher terraces that in some districts occur far above the present valley-bottoms.

Physical Features.

The district consists of two distinct parts:—1. The monotonous low plain westward from the old mouth of the Ouse, formed by the Alluvial beds of the Fenland, which is practically at about sea-level, except for the slight rises of Boulder Clay on the north-west. 2. The diversified rising ground of the Cretaceous beds of Norfolk. This may be said to consist of two members: firstly, a westerly slope of a more or less irregular character, and, indeed, on the south broken up into two, or sometimes three, ridges with narrow plateaus between, where there is a broader outcrop of Lower Greensand, but always ending upward with the constant slope of the gentle Chalk escarpment; and, secondly, the higher table-land of the Chalk and its great Drift covering, much cut up by the many valleys that have been worn through it, including the slope all along the northern coast, that seems to be one side of a valley of which the other side has been lost, possibly pointing to a former easterly course of the Ancient Ouse, on its way to join the Ancient Thames. The southern side of this old valley runs eastward, far beyond our district, to Weybourn, where it would seem to turn somewhat northward, cliffs then coming on. Considerable difference of opinion, however, exists in reference to this subject (see p. 100).

W. W.

CHAPTER 2. LOWER GREENSAND.

General Remarks.

The Lower Greensand enters the district on the south, with an outcrop some four miles broad, between the Woottons and Roydon. The outcrop, however, narrows northward, until it is seen only on the foreshore beneath Hunstanton cliff. This narrowing has two causes, the slight easterly encroachment of the marshes bordering The Wash, and the slight northerly falling of the beds, from which the underlying Kimeridge Clay is seen only on the south, whilst on the north the base of the overlying Chalk sinks to below sea-level at the old village of Hunstanton.

With the exception of notes of occurrence and of local details by various observers this tract of Lower Greensand with its many villages, was almost unnoticed by geologists for many years, Rose's account of it (together with its southerly extension in Sheet 65) being the only one of any length.* It was not till Mr. J. J. H. Teall referred to the Lower Greensand of Norfolk, in 1875, that the structure of the formation in this northern part of the county was understood, but in a few pages he clearly described it, noting the three divisions, which had not been made out before.† The correctness of his view has been proved by the more detailed work of the Geological Survey, and his divisions, which he saw from Heacham to Dersingham, have been traced farther south continuously to Appleton, and then at intervals into Sheet 65, as described in the Memoir thereon.

Where these divisions are clearly marked, that is in all but the southern part of our district, they are as follows, beginning at the top:—

Carstone, a deep bright-brown ferruginous sandstone or grit, often in massive beds. Thickness about 40 feet.

Clays and loams, with casts and impressions of fossils (marine). Thickness from 0 to 30 feet.

Sand, with occasional flaggy brown stone, but mostly light-coloured. This is thicker than the other two together, and is probably over 100 feet.

The middle clayey division thins out southward, and its place is taken by thin flaggy ferruginous sandstone, with hard concretionary seams of "cindery" ironstone, often full of obscure casts of marine shells. It is possible that the presence of an impermeable bed has had much to do with the formation of carstone above, by preventing the downward infiltration of ferruginous water.

Until the existence of a middle clayey division in the Lower Greensand of north-western Norfolk had been made out, the presence of clay, dipping beneath the Carstone, on the foreshore

* *Phil. Mag.*, ser. 3, vol. vii., pp. 175-179 (1835), and *Proc. Geol. Assoc.*, vol. i., no. 8, pp. 234-236 (1862).

† "The Potton and Wicken Phosphatic Deposits," 8°, *Cambridge*, pp. 16-19.

near Hunstanton Station, led to the mistaken idea that Kimeridge Clay came to the surface there, and that the Lower Greensand therefore consisted of Carstone alone in that part. On this account, partly, the total thickness of the formation was underestimated.

The occurrence of a clayey member is suggestive of the Sandgate Beds of Surrey and Kent, which hold a like position in the midst of sandy beds, but the palæontological evidence, though somewhat meagre, is sufficient to negative such a correlation. It is rather to the north that we should turn for comparison, as MR. A. STRAHAN has pointed out in discussing "The Relations of the Lincolnshire Carstone."*

Laying stress on the difficulty of correlating the Norfolk deposits with those of Lincolnshire, MR. STRAHAN remarks that whilst on the one hand the clay of the former county seems much too thin to be taken as the representative of the Tealby Beds in the latter, on the other hand, if the whole of the Norfolk beds are taken as representing the Carstone (or uppermost division) of Lincolnshire, then we must suppose that the whole of the underlying Speeton Series (including the Tealby Beds) is absent, which would imply a rapid thinning out. The later researches of MR. LAMPLUGH (1898) have, however, shown that the latter supposition cannot be sustained, and that some portion of the Tealby Beds is certainly represented in Norfolk (see p. 23).

The term Carstone (as the name of a division) is here restricted to the highest member of the series, in which alone massive Carstone occurs.

As a local name for the middle clayey member, that of Snettisham Beds is suggested, as the outcrop runs through that large village.

For the lower sands we propose to use the term "Sandringham Sands," adopting, with slight modification, the name suggested by MR. F. W. HARMER for the whole of the Lower Greensand of Norfolk.†

In the detailed description, which naturally takes a course from south to north, following on to that in the Memoir on the country to the south (Sheet 65), we have to begin with a tract in which no divisions have been made on the map; but on crossing the Babingley River the divisions become clear, almost from the first, and thereafter we can treat the rest of the Lower Greensand tract in stratigraphic order.

DETAILS SOUTH OF THE BABINGLEY RIVER.

In the comparatively broad outcrop here the Lower Greensand is much hidden by Drift, both at high and low levels, and there are also small outliers of Gault.

Although the divisions were not traceable in this tract, yet there is some sign of their occurrence, one of the sections to be

* *Quart. Journ. Geol. Soc.*, vol. xlii., pp. 490-492 and table.
† "Testimony of the Rocks in Norfolk" (1877). Plate.

described showing a mass of flaggy stone at the top, with a thin layer of clay dividing this from the sand beneath.

A long old pit along the northern edge of Wootton Warren Wood (most of which is in Sheet 65, to the south) was overgrown in 1881; but it seemed to be all in sand on the northern side, whilst on the south there were in places cappings of loam (? decalcified boulder clay).

In a pit just eastward of the high-road, about three quarters of a mile E.N.E. of South Wootton Church, pipes of gravelly earth were seen over light-coloured sand.

At the long sandpit in the Sandringham Sands on North Wootton Common, on the north-western side of the high-road, about a mile eastward of the church, there are at top some patches of gravel, largely consisting of broken-up sandstone, and for the most part wholly so. The appearance is suggestive of an origin from weathering, and since a sandstone of like kind has been noted as occurring in the sand, one is led to think that these blocks may also have come therefrom.

This pit was being largely worked at the time of my visit, the light-coloured sand being carried along a tram-line to the railway-station. In places there was a ferruginous deposit along joint-planes, as well as in concretions.

By the border of the marsh more than a mile nearly north-east of North Wootton Church I saw clayey greensand and phosphatic nodules turned out of a ditch. The sand bordering the marsh here is boggy, being water-logged.

C. B. ROSE says :—"Between the castle and the water-mill at Castle Rising, I observed large blocks of sandstone lying by the roadside, apparently removed from the loose sand dug for domestic purposes: they varied in colour from light ash to nearly a black."*

At the western end of Roydon Common (S.S.E. of Rising Lodge) an old pit showed gravelly soil over light-coloured bedded sand, which was seen to the depth of several feet. A little lower, to the east, another pit showed some 12 feet of ferruginous stone, jointed, and with a little sand here and there.

A pit on the high ground of Roydon Common, about 1½ miles south-westward of the church (and at the margin of the map), gave the following section, in 1881 :—

Irregular carstone and sand; the bottom part generally with irregular grey loamy layers (one at the bottom being clearly marked, a laminated bluish-grey clay, with sand); up to 15 feet, or more.

Light-coloured (mostly nearly white) fine sharp compact sand; the junction with the bed above being tolerably even, as far as could be seen; 15 feet.

In a small pit lower down (? in Sheet 65) some of the light-coloured sand s agglutinated or compacted into a soft sandstone.

In another pit near the western edge of the same Common, a little over half a mile south-east of Rising Lodge, MR. G. W. LAMPLUGH saw the following section in 1898 :—

	Feet.
Top soil, with flints	1
Shattered rubbly brown sandstone and sand	4
Irregular ill-defined layer of hard tabular sandy ferruginous concretions ("ragstone"), the outer portion of some being full of casts of shells (see list, p. 27).	1 to 2
Softer, more flaggy, brown sandstone, with irregular concretions containing smaller nodules (and shells ?) ...	2
Massive brown sandstone, with ferruginous joints and incipient concretions. Obscure markings, perhaps shells...	4

* *Phil. Mag.*, ser. 3, vol. vii., p. 177 (1835).

The following is from one of ROSE'S papers :—"In a quarry . . at the Short-trees Plantation [near Roydon], there is a bed of pure white sandstone, which is used for the sills of windows and the lintels of doors."*

Under an east-and-west hedge-bank along the slope of the chalk-topped hill over half a mile N.N.E. of Roydon Church there is sand, at the top part clayey (a sandy clay), partly greyish, with some weathered calcareous nodules.

DETAILS NORTH OF THE BABINGLEY RIVER.

Lower Division.—Sandringham Sands.

Although much the thickest of the three divisions, and taking up the greatest space at the surface, there is less to be said about this than about the others. The sand is mostly light-coloured, sharp and silvery, and as a rule much finer in grain than the Carstone. In its upper part, however, it is often iron-stained, and in places cemented into a flaggy brown stone. Current-bedding of course occurs.

The outcrop is free from Drift, except at the southern margin along the Babingley Valley, and northward by Snettisham, where low-lying Boulder Clay borders the marshes. It sinks to the marsh-level north of Heacham.

Brown stone and sand were seen in a pit about two-thirds of a mile W.S.W. of West Newton Church, and flaggy stone occurs on the plateau eastward of Wolferton (Wolverton of old series maps).

At the top of the short cutting just E.N.E. of Wolferton Station the ground has been cut back for stone, and there is fine yellowish or brownish sand, firm and to a certain extent hardened, with irregular cindery erruginous concretions full of obscure casts of shells (see p. 27), altogether up to about eight feet thick, with the soil. The cutting is deep on the southern side, and in sand, mostly fine, sharp, bedded and partly false-bedded, the upper part pale brown buff and partly coarse, the lower part light-coloured. There are some thin hard ferruginous layers, one of which, just above the level of the rails, is grey in the middle (? pyrites) as also is another, about six feet above the level of the rails (? carbonate of iron).

In describing this cutting many years ago, DR. J. LOWE drew attention to spherical ferruginous nodules in the sand, consisting of concentric coats of sand hardened by iron-oxide, round a nucleus of fine loose sand. He thought that the sand had been perforated by some boring-animal, the borings seen being generally horizontal, filled with coarser sand than tha surrounding them, and with their sides hardened by iron-oxide, so as to form a tube. The nodules occurred at the end of these tubes, and, he thought, owed their formation to the presence of remains of the boring-animal.† I am inclined to think, however, that the whole thing is of purely mineral origin.

The next cutting, farther eastward, is in the lower part of these sands, the colour varying from white to pale brown in the bottom part, and *across* the bedding (white on the west, then brown, then whitish again on the east). This change of colour was seen on the clearer and higher northern side, which had been cut back for a roadway, and it is suggestive of bleaching from surface-actions, which would get more readily at the bottom part of the sand where that is nearer the surface and therefore less protected.

Beyond this, down to the marsh, the bottom part of the sand tract, north of the railway, is waterlogged and forms a very gently-inclined boggy plain, passing down to the alluvium.

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* *Proc. Geol. Assoc.*, vol. i., no. 8, p. 234 (1862).

† *Rep. Brit. Assoc.* for 1868, *Sections*, pp. 72, 73 (1869), and under a different title in *Geol. Nat. Hist. Repertory*, vol. ii., p. 247 (1868, shorter), and in a Norfolk newspaper (1868, longer).

In the sand in the lower part of the cutting there are numerous irregular, round or knobbly, pyritous nodules. All seem sandy and in some the pyrites passes into brown and red ferruginous stone. This and other facts before noted suggest that the Carstone may have derived its ferruginous matter rom oxidated pyrites.

[On Sandringham Warren there are several small pits from which thin flaggy brown stone is obtained, overlying the sharp white and pale yellow Sandringham Sands. Cindery ferruginous layers occur near the base of this stone, in which obscure casts of shells are often abundant.—G. W. L.]

At the pit marked on the map, less than a mile south-west of Dersingham Church, the sand was firm and in parts hardened to a crumbling stone. This seems to be the section alluded to by FITTON as showing "white sand under yellow slightly consolidated sand."*

ROSE'S note of the occurrence "at Dersingham Heath" of "*Nautilus radiatus*, a *Thetis*, and a *Natica*"† does not enable us to fix the locality; for there is no such name on the map. The fossils probably came from the flaggy stone above mentioned (see also p. 20).

In a pit a little north-east of Snettisham railway-station a thickness of four feet of loamy beds was seen near the top of the sand.

In the railway-cutting, over half a mile W.N.W. of the same place, there is crimson sand amongst the light-coloured.

Beyond this the Drift greatly hides the sand, but in 1898 it was exposed in a shallow pit beneath the clay at the brickyard nearly a mile S.S.W. of Heacham Church.

Middle Division.—Snettisham Beds.

This division of the Lower Greensand has been traced, in a continuous outcrop, from south of Appleton, near the Babingley River, to Heacham, at which latter place it is partly hidden by Gravel and Alluvium, and to the north by low-lying Boulder Clay; but it has been seen again on the foreshore near Hunstanton railway-station and in the foundations of the pier.

It thickens northward, and, though there is a fairly broad outcrop south of the village of Appleton, along the rather sharp slope from that place northward to Dersingham the outcrop is so narrow that it can only be shown on the map by a line.

Then, however, it broadens somewhat, probably through the setting in of argillaceous material at a lower horizon than that hitherto seen, so that northward from Dersingham both the upper and lower boundary-lines can be drawn, the two mostly near together, where not on flatter ground.

From Snettisham the outcrop runs out as a westerly spur along the marked slope of Lodge Hill, and from Horsewell to Heacham the outcrop is broader than usual, though slightly hidden by Drift.

Along part of its winding course this outcrop is sometimes traceable from causing a zone of dampness, the clay stopping the downward percolation of water from the Carstone.

In this division casts of marine shells, of the same age as the beds, occur rather plentifully (see list on p. 25).

At Appleton the clay is shown in some pits about a third of a mile south of the church and again in ditches, ponds (old pits), &c., south of the church. It seems to take up some area at the surface, though probably thin, and its outcrop is not far from the boundary of the Gault, so that the sand between can be of no great thickness.

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* *Trans. Geol. Soc.*, ser. 2, vol. iv., p. 313 (1836).

† *Geol. Mag.*, vol. iv., p. 31 (1867).

Clay was also seen in a ditch, by the foot of the slope south of east from West Newton Church, the bottom six inches being ferruginous, sandy, and with scattered small pebbles and phosphatic nodules. Beneath this, sand, mostly with a little ferruginous stone at top, was seen.

By the high road just north of the sixth milestone, north-east of Babingley, I saw lying about some pieces of grey clay, like that of the Lower Greensand ; so that there may perhaps be a small outlier under part of the gravel hereabout, though the ground seems low for this clay to occur in place. Possibly the clay may be a slipped mass, or a transported boulder, or it may be a layer in the gravel, merely looking like that with which we are now concerned.

On the southern slope of the hill, a little south-east of the lodge on Sandringham Warren and about a mile E.S.E. of Wolferton Station, is an abandoned brickyard. No good section was to be seen, in 1882, but the sides of the pit showed sand and carstone, the floor being of grey clay. MR. TEALL has noted that the clay is here apparently overlaid by white sand.* Just below, within the brickyard, were some pits in light-coloured sand, loamy just at top. The clayey beds therefore must be thin here.

Signs of their presence were seen at the two re-entering angles of the line engraved on the map about half a mile N.N.W. of Sandringham Church and midway between them.

The wood up the little valley, about a third of a mile south-eastward of Dersingham Church, is very springy and boggy from water being thrown out of the ferruginous sand by the underlying clayey beds.

Just south of the lane, less than a quarter of a mile S.S.E. of the church, under the hedge of a garden at the top of the sharp slope, by a dam (? old fish-pond) and close to the road on the west the following section was seen in 1898 by MR. LAMPLUGH :—

Soil	1 foot.
Brown weathered loamy material, with an irregular layer of small pebbles (= weathered upper part of ferruginous band in next section)	2 feet.
Brown loamy sand, with small smooth pebbles, and bits of pale phosphatic stone ; also a phosphatic nodule, with dark interior, 4 inches diameter, full of casts of fossils, including *Crioceras*? (undeterminable fragment); *Pinna* sp., *Cytherœa* sp., &c.	6 inches.
Indurated seam of brown sand, passing streakily into the sand below. A large bivalve (*Pleuromya ovalis*) in the attitude of life, 6 inches below the pebbly band.	Seen to over 4 feet.
Pale silty sand with yellow streaks = Sandringham Sands	

A better section is visible in the above-mentioned lane, east of the schoolhouse, where the following succession can be traced in the southern bank of the shallow road-cutting, the beds being much less affected by weathering than in the former exposure.

Stiff grey clay with occasional flat decomposed "box-stone" nodules. No fossils found	Seen about 5 feet.
Rusty-brown, changing to brick-red, band of clayey ironstone, full of iron-shot grains, and with a sprinkling of small smooth pebbles up to quarter inch diameter, containing casts of *Pleuromya*, &c. ; and small tubular concretions like the ironstone at Lodge Hill ; sharpish junction with clay above, but merges into clayey loam below, which rests on	2 to 3 feet.
Fine whitish-grey or buff sands, with thin silty seams = Sandringham Sands...	Seen about 5 feet.

The upper brown loamy pebbly beds of the first section evidently represent the ironstone band in the lane, thoroughly leached and weathered. The important relation of these sections to those to the northward and southward is discussed on p. 20.

G. W. L.

* "The Potton and Wicken Phosphatic Deposits," p. 19 (1875).

Clay was again seen at three quarters of a mile east of the railway-station, and in the bend of the road close by, westward.

The brickyard on the eastern side of the high-road about three quarters of a mile north-westward of Dersingham Church has long been abandoned, and the pit (about 12 feet deep) has fallen in, but in 1882 the following imperfect succession could be made out:—

Wash of brown sand.

Clayey beds. At top pale grey clayey sand and loam; then, light grey clay, with ironstone nodules, of which there were many on the floor of the pit. Below this a little red clay (with buff and grey) was seen.

Fine buff and brown sand (? any clayey layer in it).

FITTON says:—"In a brickfield near *Mount Amelia* I found casts of the following shells, in masses of agglutinated ferruginous sand," and he names seven, besides "some other indistinct bivalves and univalves."* Some of the names are those of Upper Greensand species, so that the identifications are doubtful and not worth reproducing, but the genera agree well with those present in the Snettisham nodules.

Round Ingoldisthorpe clay was seen in several places, from nearly half a mile south-south-westward of the church to about a third of a mile east of it, in which latter part there is a broader outcrop in the little valley.

At the brickyard, a third of a mile south-west of Snettisham Church, a thickness of about 12 feet of grey sandy clay and clay with a ferruginous layer was seen, and there seemed to be some red clay at the bottom. Casts of shells have been got in ironstone nodules, of which some were lying about in the pit.†

An old pit in the wood at the south-western end of Lodge Hill showed about 15 feet of grey sandy clay, weathering brown, with some ironstone-nodules in the top part, and below the middle a hard fossiliferous ferruginous sandy bed, six inches or more thick (see p. 19).

It is probably this pit of which MR. TEALL has given the following section, which he must have seen when clearer. He describes it as "in south-west face of Lodge Hill," and as "a good section, showing the relations of the clay to the carstones above and the sands below."‡

Soil.

Base or wash of Carstone. Red sand, 2 feet, passing down into the next.

Middle Division (top doubtful)	Yellow and white clayey sand.
	Laminated clayey sand, 1½ feet.
	Dark grey stiff clay, 4-5 feet.
	Clayey sand, with concretions of ironstone, 2 feet.
	Sandy clay, with fossils (*Lucina*, *Pecten orbicularis*, &c.)

The woodcut-section through Lodge Hill, given by MR. TEALL, errs in showing an outcrop of Kimeridge Clay, the clay seen at the western foot of the hill being Boulder Clay, and the lower member of the Lower Greensand going down to marsh-level on the south.

MR. SKERTCHLY noted springs, thrown out from the overlying carstone, just eastward and more than half a mile north-eastward of Lodge Farm. Less than half a mile north-eastward of that farm I saw carstone over loamy and sandy clay, in a pond, by the western side of the track.

Clay was seen by the bend of the road northward of Horsewell.

At the old brickyard farther north (nearly a mile S.S.W. of Heacham Church) a thickness of about 12 feet of clay and sandy clay was at one time visible but is now overgrown. The earth was grey, the upper part being rather the darker and ochreous-stained, and there being a red ferruginous layer in the middle, with lumps of soft stone just below. This was on the

* *Trans. Geol. Soc.*, ser. 2, vol. iv., p. 313 (1836). He also remarks that Fuller's Earth was said to occur in the Lower Greensand at Ingoldisthorpe (*Ibid.* p. 306).

† This yard was not being worked in 1898, but some shells and impressions of ferns were found in the ironstone nodules.—G. W. L. (See p. 19.)

‡ "The Potton and Wicken Phosphatic Deposits," p. 18 (1875).

western side ; on the other the red bed was not seen, but the clay reached higher.

The existing brickyard joins on, to the north, and carries the section upward, in like beds, to a higher level. In 1898 the following section was exhibited partly in the pit, partly in a sinking through the floor carried down to the underlying sand :—

Section in the bank at the eastern end of the brickfield, by G. W. LAMPLUGH.

Weathered top-stuff; brown loam with scattered pebbles of flint, &c.	3 to 5 feet
Weathered brownish and bluish clay	5 „
Dark blue tenacious clay, with decomposed pyrites and a decomposed pyritous layer at the base ...	1½ „
Tough palish blue-brown clay, with pale brown pyritous concretions containing fossils : *Crioceras Emerici? &c.* (see list, p. 25). Seen in bank for ...	3 „

Continuation of section in a sump at eastern end of brickfield.

Tough dark brown and blue clay, passing into ...	6 „
Dark pyritous silt	2 „
Clay (*fide* workmen ; only uppermost portion visible) (The material thrown out of the sump showed that a layer of small irregularly-oval hard bluish-grey claystone nodules, full of grains of coarse grit, occurred at the bottom of the clay. Some of these were covered with worn *Serpulæ* and penetrated by borings, but I saw no other fossils in them.)	7½ „
Sand (*fide* workmen) ; to water... ... ... (Pale yellow sand, with some coarsish grains, had been thrown out from the bottom of the sump.)	2 „

A sandpit at the entrance to the yard showed 6 feet of pale grey and yellowish sand, chiefly fine in texture, but with coarsish streaks, and with thin seams showing deep ferruginous staining ; = Sandringham Sands.

G. W. L.

Farther on clay was seen in places, until the outcrop was wholly masked by gravel.

On its reappearance, on the northern side of the narrow Alluvium of the side-valley, clay was again seen just south-east of the church.

After a short course north-westward, through the park, the outcrop is again, and finally, hidden under Alluvium and Drift, and the last known of these clayey beds is that they were found in sinking piles for the pier at Hunstanton. The beds are also said to have been exposed on the neighbouring foreshore, presumably when the sand had been swept away, and MR. JOHN GUNN saw them farther west [? south] at low tide, when the beach had been scoured away.

Upper Division.—Carstone.

This upper sandy member is almost wholly cemented by iron-oxide into a soft stone, here usually massive and thick-bedded ; more so indeed than anywhere else along the outcrop of the Lower Greensand that borders the northern side of the London Basin ; so that it yields the chief building-stone of the county.

As might be expected from the character of the deposit, fossils are scarce, and, excepting the fragments of wood, nearly all are contained in eroded phosphate nodules and masses of hard grit near the base of the deposit.

These fossils have been fully noticed by MR. W. KEEPING, whose work will now be quoted.*

* "The Fossils and Palæontological Affinities of the Neocomian Deposits of Upware and Brickhill," 8°, *Cambridge*, 1883, pp. 32-34, 56 (but not always following this order).

"The richest of these derived phosphatised Neocomian faunas is that of Hunstanton, where the following species were collected for the Woodwardian Museum": —

	Ammonites	cornuelianus, *d'Orb.*	× Ancyloceras gigas, *Sow.*
×	„	Deshayesii, *Leym.*	Ancyloceras, tuberculated sp.
×	„	Martini, *d'Orb.*	Nautilus.
	„	sp. (allied to Koenigi).	Pleurotomaria.
	„	2 sp.	Perna Mulleti, *Desh.* (some derived, some looking like natives).

Farther on he describes the beds as "a set of ironsands and pebble beds with a zone of nodules near the base. . . Fossils occur rather rarely in this bed, in the . . . nodules"; and the forms marked × in the above list "are all good Upper Neocomian or Aptien species very characteristic of the Atherfield clays—to which beds MR. WILTSHIRE has consequently referred the Hunstanton series. But so far as I have seen or been able to learn all the Hunstanton species are 'derived' fossils. . . They are all either . . . rolled phosphatised casts, or are found in the hard rolled lumps of dark iron grit [see below] . . . so that these fossils instead of proving the bed to be of Atherfield clay age, really show that it is of some age posterior . . . though it is probably not far removed."

"Comparing the Hunstanton bed directly with the Upware Nodule bed we find some resemblances between the two lithologically, also in the contained phosphatic nodules and pebbles; and particularly in the species of derived Neocomian fossils . . . and I consider that, notwithstanding the absence of a true indigenous fauna . . . we have good reason to consider the Hunstanton and Upware sands and pebble beds as belonging approximately to the same age."

After noticing the occurrence at Upware and Potton of "a peculiar dark-coloured grit rock, containing a special fauna," he goes on to say:—"At Hunstanton large masses of exactly similar rock as big as large cannon-balls are found in a zone beneath the carstone and above the clay." I think, however, that he is mistaken in looking on these blocks as boulders, and that they are rather concretionary or weathered masses of one of the marked hard beds occurring there.

"From these blocks we have in the Woodwardian Museum the following," with some marked × added from the table on p. 34 of the book, and others, marked E, on the authority of MR. R. ETHERIDGE.*

Cephalopoda.

E. Ammonites cornuelianus, *d'Orb.*	Hamites or Ancyloceras, small sp. with double row of spines along back.

Gasteropoda.

E. Dentalium.	Solarium neocomiense, *d'Orb.*
E. Pleurotomaria gigantea, *Sow.*	Tornatella.
Scalaria.	× Trochus.

* In MR. WILTSHIRE'S paper, *Quart. Journ. Geol. Soc.*, vol. xxv., p. 189 (1869).

Lamellibranchiata.

E. Avicula macroptera (?)
Cardium subhillanum, *Leym.*
Corbula.
Cytherea (Venus) orbigniana, *Forbes.*
E. Dianchora (Spondylus).
Goniomya rauliniana, *d'Orb.*
E. Isocardia angulata, *Phil.*
E. Leda.
Lucina (E. L. crassa, *Sow*).
Nucula (E. N. planata, *Desh.*).
Pecten orbicularis, *Sow.*
× „ striato-punctatus, *Rom.*
E. Pectunculus.
× Perna Mulleti, *Desh.*
× Pholadomya.
Scrobicularia phaseolina, *Phil.*
E. Trigonia.
× Small triangular bivalve.

Brachiopoda.

E. Terebratula biplicata, *Sow.*, (? prælonga).

Fragments of Wood.

This upper division has a much narrower outcrop than the lower division, with a breadth for the most part under a third of a mile, the exceptions being where spurs run out (at Sandringham Warren and at Lodge Hill, Snettisham) or where valleys have been cut back (at Ingoldisthorpe and at Heacham). It is only where carstone is well developed that notable sections were seen.

On either side of Appleton sand occurs, but at West Newton Church there is carstone. At Dersingham sand seems to come just above the clayey division, a quarter of a mile south-east of the church, whilst Carstone was seen N.N.E. of the same.

At Snettisham carstone occurs, just above the clay, on the road an eighth of a mile south-westward of the church, whilst just northward of the village are our first good exposures.

The large pit about a third of a mile N.N.W. of the church gave the following section in 1885 :—

White Chalk. A trace at the highest part. Fallen pieces show this to be hard.

Red Chalk, loose and weathered.

Lower Greensand.
- Hard ferruginous sand, with whitish layers.
- Carstone. In some blocks from the soft top part there were pebbles. *Terebratula biplicata*, Sow., *Serpula*? (crushed), and *Spongia* were found in brown gritty sand about two feet down.

Of the firm carstone, blocks up to 15 inches cubed were worked. There was another pit close by and another to the west, by the high-road.

The carstone here is very massive and some blocks showed beautiful iridescent surfaces, due to infiltration along joint-planes, and almost as richly coloured as peacocks' feathers. Its upper portion, known as "ragstone" by the quarrymen, is harder, more flaggy, and of a redder brown than the massive lower beds.

At Lodge Hill sand has been seen over the clay at one part and carstone at another (see p. 11). Carstone was also seen on the western side of the high-road an eighth of a mile south of Horsewell.

At Heacham the stone has been worked on the northern side of the railway, a quarter of a mile eastward from the church.

At Hunstanton, a little southward of the railway-station, the entrance to a chalk-pit showed brown sand underlying the Red Chalk. Carstone has also recently been revealed at the base of the gravel-pit adjoining the Hunstanton Gasworks (see p. 91).

We now come to the long cliff-section, and, at the risk of some repetition, it may be well to give a general account of this, leaving the details of the Red Chalk, of the Chalk, and of the

Drift to follow under those headings. At first the low southern part of the cliff consists of Drift, a reddish boulder clay; but the Lower Greensand rises up northward, and takes up the whole cliff to where the steps up to the top are placed, where the Red Chalk comes on above, to be succeeded at once by the Lower Chalk. From the slight northerly fall of the beds the Red Chalk sinks to a lower level in that direction, so that at the northern end of the cliff we find only White Chalk, the Lower Greensand and the Red Chalk passing below the beach-level about where the coast turns to the north-east.

The following notes of the succession of beds were made in 1880:—

White Chalk.

Hard white chalk, massive, bedded and jointed, the joint-planes mostly stopping at its base. Very firm, so that it overhangs in places. In the lower part some beds like the next in character.

Grey chalk, hard, weathering to a rough surface, somewhat sandy, full of broken shells of *Inoceramus*, with a nodular structure in parts. Some of the joint-planes run through to the base of this, the *Inoceramus*-bed of authors. From about 2 to 2½ feet.

Whitish and cream-coloured hard nodular chalk, with sponge-like branches, in the upper part chiefly, and showing "striated structure" (pseudomorph of calcite after aragonite). From 18 to 15 inches.

Red Chalk.

Pinkish-red chalk, with broken shells of *Inoceramus*, *Belemnites*, and a few small pebbles. Sometimes not very markedly divided from the bed above, when seen close, though from a general point of view the division seems marked. Not so clearly seen where the bed dips down to a low level. About 18 inches.

Red chalk, the lower part softer, and the bottom part sandy, with glauconite-grains, apparently passing into the bed below. Contains a good many small pebbles.

Carstone, in great part with small pebbles, especially in certain layers; one marked pebbly bed some way down, weathering very dark. Some of the unweathered joint-planes are filled with thin veins of quartz.

The carstone of this cliff differs from that worked at Snettisham in being of a coarser character, a grit rather than a sandstone to a great extent. It is somewhat fossiliferous (see p. 13), and MR. WESTMORELAND (who had a large collection at the lighthouse) told MR. WOODWARD, in 1878, that the most fossiliferous part came just above the clay, on the south, and consisted of a nodular bed with *Perna*, &c. MR. WILTSHIRE, indeed, says that for "the space of 30 feet below the . . . Red Chalk no fossils have been hitherto found at Hunstanton in the Carstone."*

ROSE† has described part of the carstone here as a breccia, which he says "can be seen only at Hunstanton," adding that it had been considered the base of the division, but that, at low water, he had found a layer of the ordinary character beneath this and saw the latter resting on the clay. The term breccia is, of course, incorrect, the included stones, &c., being rounded.

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* *Quart. Journ. Geol. Soc.*, vol. xxv., p. 189 (1869).
† *Proc. Geol. Assoc.*, vol. i., no. 8, p. 235 (1862).

Caves are said to have been hollowed out in the rock by the action of the sea, but none were seen at the time of the Survey.

The foreshore here gives an interesting exposure of hard beds, which are in part very clear, and show the slight northerly dip (1883).

There are signs of an outcrop of a hard bed starting from about the middle of the pier.

A marked hard bed begins at about the landward end of the pier, and shows for some way northward, probably continuing (after interruption from sand) in some of the ridges shown far out, at low water. The seaward bottom edge of this bed is conglomeratic, and with some phosphatic nodules.

Another marked hard bed begins just beyond the end of the sea-wall, at the steps (where the Red Chalk comes on at the top of the cliff), and runs along the shore for some distance, to beyond the highest part of the cliff (before reaching the light-house), and has a fairly broad outcrop.

The third marked bed is the top one, along the shore at the far end of the cliff, and it is formed by the dark conglomeratic bed, which is shown along the cliff. These rocks show a double set of joints, which cause the bed to weather out into large blocks, the view of which, from the top of the cliff, may be described as like an enormously magnified paddle of Ichthyosaurus, projecting from beyond the beach.

W. W.

Supplementary Notes on the Norfolk Lower Cretaceous Rocks.

[The following notes on the Lower Cretaceous Rocks of Norfolk have been furnished by Mr. G. W. Lamplugh, who re-examined the chief sections while this Memoir was in the press (June, 1898), in collecting information for the General Memoir on the Lower Cretaceous Rocks of England. The subject will be more fully discussed in that Memoir.]

The chief result of my investigation has been to show that the distinction between the Lower Sands—for which I propose to use the term "Sandringham Sands"*—and the Upper Sands or "Carstone" is more definite than has hitherto been supposed. Northward of Dersingham, the upper limit of the Sandringham Sands is fixed by the Snettisham Clay, as described in the foregoing pages. Southward of Dersingham, the lower part of this clay appears to pass into a thin-bedded flaggy brown ferruginous sandstone, with a fossiliferous band of concretionary ironstone towards its base, which is prolonged southward as a capping to the Sandringham Sands after all the clay has disappeared, being traceable across the area on the southern margin of Sheet 69, and into that of Sheet 65, wherever the top of the sands is exposed. This band has been confused with the true Carstone, but is, I

* Adopting and restricting Mr. Harmer's nomenclature; see note on p. 6.

think, distinct from it. It is well exposed on Sandringham Warren, east of Wolferton, where the words "FLAGGY CARSTONE" are engraved on the map.

It does not occur in massive beds like the Upper Sands or true Carstone, and can usually only be raised in thin flaggy fragments of soft sandstone, such as have been used in building Wolferton Station, or in irregular hard tabular lumps of concretionary ironstone, called "ragstone" by the quarrymen. The fossils of this ironstone are preserved only in the form of obscure hollow casts, giving the rock a "slaggy" or "cindery" aspect. They consist of marine shells, of which, in most cases, the genus only can be determined, along with fragmentary plant-remains and wood (see list, p. 27). The condition of the rock suggests that a calcareous constituent has been removed by percolation, and that at the same time the ferruginous constituent has been altered and rearranged, partly obliterating the fossils. In its original condition, it probably resembled the calcareous clay-ironstone concretionary bands in the Snettisham Clay at Snettisham and Lodge Hill. The best localities for obtaining the fossils of this horizon are the top of the cutting immediately to the eastward of Wolferton Station, the shallow stone-pits on Sandringham Warren, west of the high-road, and the small quarry on Roydon Common, a little over ½ mile S.E. of Rising Lodge, described on p. 7.

The steep flat-topped features of the western side of Sandringham Warren, and of Roydon Common and the country to the southward in Sheet 65, are due to the superior hardness of this rock, capping the incoherent Lower Sands.

Sandringham Sands.—Of the numerous fine sections in these sands in the southern part of the sheet, that in the railway-cutting at Wolferton is at present the best, the material being extensively dug there for ballast. On Grimston Common, in the northern part of the adjoining Sheet 65, there are large pits, whence, I was informed, the sand, besides being used as ballast, is exported to the West Riding of Yorkshire, and other places, for glass-making, &c. The material is, as a rule, much finer in texture than the Upper or Carstone Sands, and generally of a silvery white or pale grey colour, though in places stained buff, yellow, reddish, or pale brown. It is intercalated with silty layers, often so fine-grained as to retain water. In general appearance, it recalls the sands of the Hastings Series of the South of England, and bears little lithological resemblance to the Spilsby Sandstone of Lincolnshire. I found no opportunity for studying its base, which appears to contain some greensand and phosphatic nodules (see p. 7). At Downham Market, in Sheet 65, layers of loamy greensand, interbedded with the silvery sand, are revealed in the large pit in the lower portion of these sands, 300 to 400 yards S.E. of the church. Near the northern margin of the same sheet, thin streaks of fine clay were observed in several localities in the upper part of the sands, and I think it probable that the clays which have been mapped in this sheet at Gaywood, Leziate, and Ash Wicken are lenticles, intercalated with the upper part of the Sandringham Sands, and therefore at

a slightly lower level than the Snettisham Clay of Sheet 69. The only fossils which I could detect in these sands, or in the above-mentioned clays, were vegetable fragments and wood. The clay-stone nodules from the clay at Brow of the Hill brick-yard, Ash Wicken (Sheet 65), contain minute fragments of plants, unmixed with other remains, in such abundance as to suggest that the deposit had accumulated in the immediate proximity of land, and possibly where the conditions were not purely marine. Indeed, the general aspect of all except the lowermost portion of these Sandringham Sands seems to me to be suggestive of estuarine conditions.

Snettisham Clay.—Of the clay-pits in this division mentioned in the foregoing pages I found that the only one now being worked is that at Heacham, where the section given on p. 12 was revealed. I was able, however, with some difficulty, to obtain fossils also from the old pits at Lodge Hill and Snettisham, and in the road-cutting and bank at Dersingham, as mentioned on p. 10.

At Heacham, the fossils occur as sharp casts, enclosed in pale brown clay-stone nodules with septæ of iron pyrites. These are most abundant in a band about 10 feet from the top of the section ; indeed, the whole of the fossils obtained by me were probably from this horizon, with the exception of *Serpula* sp., which I noticed in small pyritous nodules thrown out from the base of the clay, in the sinking below the floor of the pit. *Crioceras Emerici* (?) and a second species, *C. Hillsi* (?), are the commonest fossils, and with these are associated beautifully delicate casts of a small *Cerithium* and other gasteropods, and of numerous small lamellibranchs, of which the little *Corbula*, found also at Lodge Hill and Snettisham, is the most abundant. Fragments of plants occur, but are rarer and not so well preserved as at Snettisham. One of the nodules which I examined appeared to be the cast of a portion of the large *Pecten cinctus*, though scarcely determinable. The probability of the occurrence of this species in the section is rendered stronger by the fact that I afterwards obtained a recognisable specimen from the old pit at Lodge Hill. A list of the Heacham fossils, as far as determined, is given on p. 25. MR. TEALL has recorded "two species of Ammonites, one unquestionably *A. Deshayesii*," from this locality,* but does not mention the occurrence of *Crioceras*. His specimens have unfortunately been mislaid, and, with his concurrence, we have thought it better to omit *A. Deshayesii* from the list pending further confirmation, since the general character of the fauna suggests a somewhat lower horizon than that at which the species is usually found.

When exposed to the weather the nodules in this pit decompose curiously into a series of concentric layers with a hollow centre, the fossil impressions being thereby obliterated. In the other pits, while some of the concretions possess the same peculiarity, there are fortunately others which weather differently, and in such fashion that the casts of organisms are not destroyed.

* "The Potton and Wicken Phosphatic Deposits," p. 17

In the old pit at Lodge Hill, now almost overgrown with trees, the casts are excellently preserved in large, irregular masses of sandy or loamy ironstone, which form a band about one foot in thickness, 9 or 10 feet from the top of the north-eastern corner of the pit. This is probably the "Argillaceous Sand, with ironstone concretions," of MR. TEALL'S section.*

The rock is sprinkled with small, bright, "iron-shot" grains, like the Ironstones of the Tealby Series in Lincolnshire, and has also a scattering of small smooth "lydite" pebbles like those in the Carstone. The fauna is more varied than at Heacham, and with a better exposure it is evident that an extensive series might be collected. *Pecten orbicularis* is the commonest fossil, but along with it are many other lamellibranchs and a few highly ornamented gasteropods of the genera *Cerithium*, *Trochus*, &c. A single hollow cast of *Belemnites* was found, to which further reference will be made. Smaller highly fossiliferous oval nodules, about the size of large potatoes, occur immediately above the band of ironstone. I obtained a few fragments of ferns, in better condition than the plant-remains at Heacham, but not so good as those at Snettisham. Traces of shells were visible in the clay immediately underlying the ironstone, but the matrix was too much weathered to permit their removal or identification.

The Snettisham pit, now no longer worked, is evidently on the same horizon as the Lodge Hill pit. In one part of the brickyard the ferruginous band has been left as a working-floor, but the stone has weathered like the Heacham nodules, and almost all traces of its fossils have vanished. The smaller harder concretions, however, which overlie it here as at Lodge Hill, are crowded with beautiful casts of shells, &c., along with rather well-preserved portions of the fronds of ferns, and from these I was able to make an extensive collection. As in the similar nodules at Lodge Hill, by far the most abundant forms are the delicate *Cerithium*, the small *Corbula*, *Pecten orbicularis*, and *Thetis Sowerbyi*. Among numerous other fossils, two casts of *Belemnites* were obtained; also fragments of *Crioceras Emerici* (?).

In all the sections, the clay is streaky and variable, some layers being of stiff tenacious mud or clay, while in others the argillaceous material is largely intermixed with sand or silt. From the general character of the deposit, we might expect anywhere to find changes in its lithological composition, such as are indicated by the Dersingham sections described on p. 10.

In this locality, in the lane east of the school-house, we find a band of clayey ironstone, sprinkled with "iron-shot" grains and small pebbles, like that of the Lodge Hill pit, overlain by stiff greyish clay with ferruginous nodules, and underlain by and passing down into the clayey loam which caps the Sandringham Sands. But in the section in the bank only about 100 yards farther south, so far as the weathered state of the exposure will permit us to judge, there appears to be no clay below the gritty ironstone band, which thus rests directly on the Sands. In both

* "The Potton and Wicken Phosphatic Deposits," p. 18.

sections I found fossils in the ferruginous band The clays are considerably reduced in thickness at this point, and I think the facts justify the supposition that the ferruginous band is the prolongation of that of Lodge Hill and Snettisham, and that in these sections we see the southward thinning out and disappearance of that part of the Snettisham clay which underlies it.

Where the top of the Sandringham Sands is next exposed, in the pits on Sandringham Warren, three quarters of a mile farther south-west, it is overlain by the "cindery" ferruginous "ragstone" rock, with casts of shells, &c., which has already been described. The Dersingham sections thus supply the link which, I think, connects this fossiliferous band with the fossiliferous horizon in the Snettisham Clays.

In Norfolk, as in Lincolnshire and in Yorkshire,* the Lower Cretaceous Clay probably thickens north-eastward, and thins out rapidly or passes into sand south-westward, as the mapping in this sheet indicates. Southward of Dersingham we are evidently at the margin of the area of deposition of the argillaceous material of the Snettisham beds.

Carstone.—I did not succeed in finding any section in the interior in which the junction of the Carstone with the Snettisham Clays was definitely exposed, the rubble at the top of the Lodge Hill pit being probably not in place. At Hunstanton, on the shore near low-water, I found that hard grey clay had been thrown out in preparing the foundations of the piles for an extension of the pier, but this part of the shore was, as usual, covered with sand. We know, however, from the statements of previous observers, that after storms the base of the Carstone is sometimes exposed at this place. On a previous visit in September, 1895, the conditions were better than at present, and I then saw the following succession on the foreshore north of the pier, which must have reached very nearly to the base of the Carstone. The exposed beds ran obliquely across the foreshore from not far below high-water mark under the pier to low-water about one-third of a mile farther north, as follows :—

Carstone of the cliff and upper part of shore.	
Dark coarse Carstone, weathering rustily, but often dark green within the blocks	about 5 feet.
Finer yellow soft car-sand	„ 2 to 3 „
Yellow coarsish Carstone with ferruginous concretions generally inclosing pieces of fossil wood	„ 1 „
Pebbly yellow Carstone with yellow phosphatic fragments and fossiliferous dark brown phosphatic nodules	„ 2 „

In the nodules, *Amm. Deshayesii* is the commonest fossil, in more or less imperfect condition, generally having the worn and corroded aspect usual to fossils preserved in this kind of nodule.

Nautilus sp. and fragments of a Crustacean also found.

Green clayey sand, with scattered coarse pebbly grains, seemed to underlie the fossiliferous bed, but was not clearly exposed.

It is from the nodule-bed that the so-called "derived phosphatised" fossils, mentioned on a previous page, have been obtained.

* See *Quart. Journ. Geol. Soc.*, vol. lii., p. 206.

I have already elsewhere* stated my conviction that this fauna is at its proper horizon, and cannot, strictly speaking, be considered derivative. And this conviction has been strengthened by my recent investigation, and by a re-examination of the specimens in the Woodwardian Museum and at Jermyn Street. The fauna is not mixed, but is consistent throughout, and is *newer* than that of the Snettisham Clay.

It is equivalent either to that of the lower part of the Hythe Beds or of the upper part of the Atherfield Clay, further palæontological work in the South of England being necessary before the correlation can be more precisely stated. Meanwhile, the important result is suggested that, since there is nowhere any definite break between the upper part of the Carstone and the Red Chalk, the Carstone, as a whole, may represent the combined Hythe, Sandgate, and Folkestone Beds of the South of England.

The Carstone pits, near Snettisham, have been considerably enlarged in recent years, to supply building material for the rapid growth of New Hunstanton and Heacham, without, however, revealing any new points of importance. They do not go down to the base of the deposit, but I was informed that at the lowest level reached, large pieces of fossil-wood were frequently found, and it is probable that this is at the same horizon as the similar band on the Hunstanton shore, mentioned in the section given above.

One of the old pits, south-west of Bilney Lodge, in Sheet 65 (referred to in the Memoir on the Sheet, p. 15), still presents a good section in this division, but elsewhere south of Snettisham I saw no good exposures of the true Carstone.

Notes on the Palæontology and Correlation.

The fossil-lists given on pp. 25-27 have been prepared in the Palæontological Department. They are based entirely on the specimens in the possession of the Geological Survey, collected during my recent visit to the localities, together with a few obtained by MR. RHODES from Heacham, Lodge Hill, and Snettisham, in 1881. In several of the fossils from the clay-pits it has only been possible at present to give the genus, some probably belonging to new species. This applies especially to the small *Corbula*, and to *Gervillia*, *Arca*, *Perna*, *Cerithium*, and *Trochus*. The specimens from the "cindery" ironstone of Sandringham Warren, Wolferton, and Roydon, are, however, in any case, rarely in a condition for specific determination.

The fauna is unfortunately one which, in the present state of our knowledge, cannot adequately be discussed. The palæontology of the English Lower Cretaceous rocks is in a backward state generally, and especially in regard to the lamellibranchs, which constitute the principal feature in these collections. This, we hope, will shortly be remedied by the Monograph in course of preparation by MR. H. WOODS, and meanwhile it would be useless to attempt to complete the investigation. What is

* *Quart. Journ. Geol. Soc.*, vol. lii., pp. 198 and 211.

chiefly lacking is a more satisfactory knowledge of the palæontology of the English marine Lower Cretaceous deposits older than the Atherfield Clay. The Cephalopoda of these deposits have been admirably described by PROFESSOR A. PAVLOW,* but our knowledge of the other elements of the fauna is still very imperfect.

My impression, derived partly from the general assemblage of the fossils, and partly from the occurrence of certain species and the absence of others, is that the nearest equivalent of the Snettisham Clay will be found at the horizon of the Tealby Limestone in Lincolnshire. This fossiliferous limestone forms an impersistent stratum at the top of the Tealby Clay, well developed between Caistor and Donington,† but dying out, southward, apparently being replaced in Sheet 84 by "roach," "a soft yellow ferruginous marl, containing oolitic grains of iron," which "occasionally passes into a hard ironstone rock."‡ The "roach" has not yielded fossils, but its lithological characters recall the ironstone band of the Snettisham Clay.

The variety of *Pecten orbicularis*, which occurs in most of the Norfolk sections, is one of the commonest fossils of the Tealby Limestone, but has too wide a range to count for much. *Pecten cinctus*, occurring at Lodge Hill, and possibly also at Heacham (see p. 18), is also abundant in the Tealby Limestone, and ranges downward to the Claxby Ironstone or lower.§ *Thetis Sowerbyi*, *Pholadomya Martini*, *Pleuromya neocomiensis*, *P. ovalis*, *Cardium subhillanum*, *Nuculana scapha* are also fossils of the Tealby Limestone, or of its equivalent horizon at Speeton; but they are all common "Lower Greensand" forms of wide distribution. The assemblage is one, however, pertaining to the higher horizons of the Speeton Clay—a point of some importance. *Trigonia scapha* is interesting, as I am informed by MR. NEWTON that it has been considered a shell of rare occurrence in England; it is apparently present in most of the Norfolk sections, but has not yet been recorded from Lincolnshire, where specific determinations of the forms of the Tealby Limestone are still wanting. The absence from the Snettisham beds of the forms occurring commonly at the lower horizons in Lincolnshire, viz., *Trigonia ingens*, *T. tealbiensis*, &c., tells against the correlation of the Norfolk deposit with any of the lower members of the Lincolnshire series.

Crioceras Emerici (?), the commonest Cephalopod in these Norfolk beds, is known from the middle part of the Speeton Clay, and probably occurs at the same horizon in Lincolnshire; but its upward range has not been accurately fixed. *Crioceras Hillsi* has not been recorded from Speeton or Lincolnshire, but has been found at Upware and in the Hythe beds; in Germany it appears to occupy a somewhat higher horizon than in Norfolk. The

* "Argiles de Speeton et leur equivalents," *Bulletin de la Soc. imp. des natur. de Moscow* (1891).

† See Memoir on Sheet 83, "The Geology of the Country around Lincoln."

‡ See Memoir on Sheet 84, "The Geology of East Lincolnshire," p. 19.

§ See "On the Speeton Series in Yorkshire and Lincolnshire," *Quart. Journ. Geol. Soc.*, vol. liii., p. 210.

casts of *Belemnites* furnish evidence in support of the general conclusion stated above. One of the specimens, from Snettisham, is the hollow left by a small Belemnite with the alveolar cavity distinctly indicated. A second, from Lodge Hill, gives the cast of portion of a larger specimen, from which a general idea of the outline, and especially of the section of the Belemnite, can be obtained. Of the known Belemnites of the Speeton Clay and of the Lincolnshire beds both these casts can be definitely stated not to belong to *Bel. jaculum* or its allies, which are the characteristic species of the Tealby Clay,* while the fauna which accompanies them renders it extremely improbable that they represent *Bel. lateralis* or its allies, which occupy the zone below that of *Bel. jaculum.*

Both specimens, however, can be closely matched by individuals in my collection from Speeton and from Lincolnshire which were found in the *Zone of Bel. brunsvicensis*, belonging to that or a closely allied species, *Bel. speetonensis*, both common in the Tealby Limestone.

Thus the palæontological evidence, so far as it goes, is consistently favourable to the correlation of the fossiliferous band of the Snettisham Clay with the Tealby Limestone of Lincolnshire and some portion of the zone of *Bel. brunsvicensis* in Yorkshire. This also agrees with the stratigraphical position of the clay, since the base of the Carstone contains ammonites found in Brunswick,† in beds overlying the zone of *Bel. brunsvicensis.* It is open to question whether the whole of the clay belongs to this horizon where, as at Heacham, there are several feet below the fossiliferous band, or whether the lower portion may range down to the level of the Tealby Clay of Lincolnshire; but the general aspect of the deposit, and the extent to which it is interbedded with sandy streaks, suggests that the rate of accumulation was comparatively rapid and that not more than one stage is likely to be represented in it.

The local correlation of the fossiliferous ironstone at the top of the Sandringham Sands south of Dersingham, with the ironstone band in the Snettisham Clay must rest mainly on the stratigraphical evidence already given, as the fossils of the "cindery" ironstone are not sufficiently well preserved to be of much value. The probable presence of *Trigonia scapha* in the Wolferton section is, however, a point in its favour.

A notable feature in all the fossiliferous exposures of the Snettisham Beds, is the presence of vegetable remains in considerable abundance, in which they differ from the equivalent deposits in Yorkshire and Lincolnshire, where, so far as I am aware, no land fossils excepting fragments of sea-borne drift-wood are found. In Norfolk portions of the leaves of plants appear to increase in quantity in going southward. At Heacham they are small and inconspicuous; at Lodge Hill fern-leaves are larger and more plentiful; and at Snettisham are among the commonest

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* *Quart. Journ. Geol. Soc.*, vol. lii., p. 207-8.

† See *Beitrag zur Kenntniss der Unteren Kreide in Herzogthum Braunschweig von G. Muller in Berlin. Jahrbuch der Königl. preuss. Geol. Landesanstaldt für* 1895.

fossils of the nodules. Farther south the "cindery" ironstone shows bits of wood and plants obscurely preserved in all the exposures, even where no trace of shells remain. They indicate the proximity of land and perhaps the presence of a quiet inlet receiving land drainage. This would explain some features of the molluscan fauna which are otherwise difficult to understand, to wit, the absence, so far as is known (and in any case, the rarity), of *Exogyra sinuata*, *Ostrea frons*, and other shells, usually the most abundant fossils of marine deposits of this age, and also the great number of individuals of certain species in one place, and their rarity or absence in another not far distant. The life-assemblage and the variability, like the plants, suggests that the area was affected and the fauna modified by strongly-marked local conditions. The Carstone overlying these beds is, I believe, usually considered a shore-deposit, but I am inclined to think that it may represent somewhat deeper (though yet shallow) waters, with stronger currents, than the Snettisham Beds, which would explain its wide extent and uniformity in Norfolk and Lincolnshire.

Regarding the correlation of the Sandringham Sands no definite statement is at present advisable. In position they invite comparison with the Spilsby Sandstone of Lincolnshire, but differ in so many respects from that deposit that I do not think it probable they are of the same age. One of the distinctive peculiarities of the Spilsby Sandstone is the highly polished surface of the coarse grit-grains of which it is largely composed; it also contains a peculiar marine fauna with Jurassic affinities.

The Sandringham Sands, so far as they are exposed to view in the area, are fine, unpolished, and in places somewhat loamy, and their only fossils are the bits of wood and plants contained in pyritous nodules and clayey streaks. They are probably closely allied to the Snettisham Beds in age, and if so must be newer than the Spilsby Sandstone. As hinted above, they may not impossibly be of estuarine origin.

As the base of the Sands is below marsh-level in the greater part of the area included in Sheet 69, and where it rises above, at the southern margin of this and in the adjoining Sheet 65, is nowhere open to inspection, there is some possibility that its lowermost portion may possess different characters from the rest, and may represent the Spilsby Sandstone. But the field-evidence lends no countenance to this supposition, for while the whole of this part of Norfolk, together with a wide stretch of country farther south, contains scattered glacially-transported boulders of Spilsby Sandstone with the characteristic fauna,* there is never any indication that these are of local derivation, but signs on the other hand that they have been largely obtained from the area now covered by The Wash.

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* The assemblage of fossils in some of these boulders is not quite that with which I am acquainted in any exposure along the outcrop in Lincolnshire. Along with familiar Spilsby forms one sometimes finds others in large numbers, like *Terebratula ovoides*, which are not seen in Lincolnshire. The ice has evidently had access to a local development of the deposit somewhat different from its character where now exposed.

In suggesting, however, that the Sandringham Sands are as a whole newer than the Spilsby Sandstone, and presumably equivalent to some portion of the Tealby Clay, I do not wish to make any pretence to have obtained, as yet, sufficient evidence to justify the correlation. The southward prolongation of the Sands beyond the borders of the county has still to be investigated.

G. W. LAMPLUGH.

I.—*Fossils of the Snettisham Clay.*

	Heacham.	Lodge Hill.	Snettisham.	Dersingham.
Plantæ.				
Lignite	×	×	×	
Weichselia (Lonchopteris) Mantelli (?), *Brong.*			×	
Annelida.				
Serpula gordialis, *Schloth.*			×	
Brachiopoda.				
Rhynchonella sulcata (?), *Park.* ...		×		
Terebratula sp. (cf. T. depressa, *Lam.*)		×		
Lamellibranchiata.				
Arca sp....	×			
Avicula		×	×	
Avicula sp. (cf. A. Cornueliana, *d'Orb*)		×		
Cardium subhillanum, *Leym.* ...			×	
Cardium sp.			×	
Corbula sp.	×	×	×	
Cucullæa sp.			×	
Cytheræa (?) sp.		×		×
Exogyra sp.			×	
Gervillia sp.	×	×		
Modiola (?)		×		
Nucula sp.		×	×	
Nuculana scapha, *d'Orb.*	×		×	
Pecten orbicularis, *Sow.* (an oval variety)		×	×	
Pecten cinctus (?), *Sow.*		×		
Perna sp.		×		
Pholadomya Martini, *Forbes*... ...	×			
Pinna sp.			×	×
Pleuromya ? (Panopæa) neocomiensis, *d'Orb*		×		
Pleuromya ? (Panopæa) ovalis, *Sow.*...				×

Fossils of the Snettisham Clay—(continued).

	Heacham.	Lodge Hill.	Snettisham.	Dersingham.
Thetis Sowerbyi, *Roem.*	×	×	×	
Trigonia scapha, *Pict. and Camp.* (= ? T. scapha, *Ag.*)	×		×	
Gasteropoda.				
Actæon affinis, *d'Orb.*...			×	
Aporrhais Robinaldina (?), *d'Orb.* ...			×	
Aporrhais sp. (cf. A. retusa, *Sow.*) ...			×	
Cerithium turriculatum, *Forbes* ...	×			
Cerithium sp. (near C. aculeatum, *Forb.* MS.)		×	×	
Cerithium sp.	×	×		
Dimorphosoma ancylochila, *Gard.* ...		×		
Natica sp.		×	×	
Pterocera Fittoni, *Forbes*			×	
Trochus sp.		×	×	
Cephalopoda.				
Ammonite (fragment)			×	
Belemnites sp.		×		
Belemnites sp. (B. brunsvicensis group)			×	
Crioceras sp. (cf. Emerici, *Lev.*) ...	×		×	
Crioceras sp. (cf. C. Hillsi, *Sow.*) ...	×			
Crioceras (?)				×
Vertebrata.				
Fish vertebræ			×	

II.—*Fossils of the Ironstone south of Dersingham.*

	South Pit, Sandringham Warren.	Top of cutting, Wolferton Station.	Pit at W. end of Roydon Common.
Plantæ.			
Fragments of wood	×	×	×
Annelida.			
Serpula (Vermicularia) sp. (cf. S. polygonalis, *Sow.*)	×		×
Polyzoa?			
Polyzoon (?)			×
Lamellibranchiata.			
Arca (?)			×
Corbula (?)		×	
Nucula sp.	?	×	
Pecten orbicularis (?), *Sow.*	×		
Pectunculus sp. (cf. P. umbonatus, *Sow.*) ...		×	
Tellina sp. (cf. T. inæqualis, *Sow*).	×		
Tellina (?)			×
Trigonia scapha (?), *Pict. and Camp.*	×	×	
Trigonia sp. (type of T. caudata, *Ag.*)			×
Gasteropoda.			
Gasteropod fragments		×	

CHAPTER 3. GAULT AND RED CHALK.

General Remarks.

The existence of Gault in West Norfolk was first indicated by W. Smith in his map of Norfolk (1820), and confirmed by C. B. Rose in 1835.* The proofs of its existence were accepted by Fitton in 1836, who says: "The average thickness of the Gault in West Norfolk is not more than 15 feet, according to Rose, who has traced the connection between the detached portions, indicated on Smith's map, as far as West Newton, . . . beyond that point the *blue* Gault is no longer observable; its place being occupied by the red marly stratum of Hunstanton Cliff." †

Rose's estimate of thickness is, however, scarcely correct, as the Gault is nearly 60 feet thick near West Dereham, but thins gradually northward, being about 19 feet thick at Roydon on the south border of Sheet 69. His concluding statement, too, has also been disputed, and various opinions have been held with regard to the relations between the Gault and the Red Chalk. On this point, however, we consider the view taken by Rose and Fitton to be correct.

In 1886 some doubt was thrown on the existence of Gault in Norfolk by Messrs. Reid and Sharman,‡ who thought the marl referred to it might be only the basal portion of the Chalk Marl, but the discovery in the same year of Lower Gault with *Ammonites interruptus* at Muzzle Farm near West Dereham (Sheet 65), and of Upper Gault with *Ammonites rostratus* and *Inoceramus sulcatus* near Grimston dispelled this doubt and established the existence of Gault beyond dispute.§

With regard to the Red Chalk, or Hunstanton Limestone, as it is sometimes called, a full account of the literature concerning it, and of the controversy about its precise age, has been given by Mr. Whitaker in an Address to the Norwich Geological Society in 1883.‖ To this, therefore, the reader is referred for a notice of the varying opinions held by different writers from the first mention of it by Wm. Smith in 1816 down to the discussion of it by Mr. Whitaker himself in 1883.

In this place it will suffice to say that five different views have been proposed regarding the age of the red rock:—

(1) That it represents the Gault.
(2) „ „ „ Upper Greensand.
(3) „ „ „ Gault and Upper Greensand.
(4) „ „ „ Chalk Marl.
(5) That it is partly Gault and partly Chalk Marl.

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* *Phil. Mag.*, Series iii., vol. vii., pp. 172, 180, 275.
† *Trans. Geol. Soc.*, Series 2, vol. iv., p. 312.
‡ *Geol. Mag.*, dec. iii., vol. iii., p. 55.
§ See *Quart. Journ. Geol. Soc.*, vol. xliii., pp. 549, 550.
Trans. Norw. Geol. Soc., part vii., pp. 213-222.

The first view was held by SEDGWICK, ROSE, FITTON, DAVIDSON, WILTSHIRE, and BARROIS.

The second was advocated by SEELEY.

The third seems to have been first suggested by JOHN GUNN in 1864, was accepted by JUDD in 1868, and by BONNEY in 1875.

The fourth was suggested by GUNN in 1878, was accepted by WHITAKER in 1883 as one alternative.

The fifth was suggested by WHITAKER in 1883 as the only view other than No. 4 which he could accept.

In the paper above referred to MR. WHITAKER conclusively showed that the Hunstanton Red Chalk is not likely to represent Upper Greensand so far as Upper Greensand means anything separate and distinct from Upper Gault. PROF. SEELEY compared its fossils with those of the Cambridge Greensand, which was always called Upper Greensand at the time he wrote. Since that time, however, it has been proved that the fossils of the Cambridge nodule-bed have been derived from the Gault, and that the thin layer in which they occur is the basement-bed of the Chalk Marl; hence MR. SEELEY'S palæontological argument really supports the conclusion that the Red Rock is Gault.

MR. WHITAKER relies on two arguments for his view :—

1. That he had traced what appeared to be a clayey kind of Chalk Marl northward as far as Sandringham. Hence he says the argument that the Red Chalk represents the Gault, because it comes on where the latter has thinned out, might be just as well put forward in favour of the theory that the Red Chalk represents the Chalk Marl.

2. He points out that there are a certain number of fossils in the Red Chalk that do not occur in the Gault, and are only known elsewhere in the Chalk. In the list accompanying his paper 11 such species are noted, and he thinks it is more surprising that species characteristic of the later formation (Chalk) should occur in an earlier deposit than that Gault species should continue to exist in a deposit of Chalk Marl age. Hence he agrees with the dictum of JOHN GUNN that it is "the fossils of the latest type that must be used in identifying the period" of a bed.

In 1886 an endeavour was made to obtain more definite and detailed stratigraphical evidence concerning the relations of the Chalk Marl, Gault, and Red Chalk in West Norfolk, and the results were published in 1887.* In this paper it was claimed that the following points had been ascertained :—

1. That the soft Chalk Marl thins out entirely within the area of Sheet 65 (before reaching Roydon).

2. That the base of the Chalk Marl at Roydon is a hard cream-coloured limestone, which passes northward into the so-called "sponge bed of Hunstanton."

* JUKES-BROWNE and W. HILL, "On the Lower Part of the Upper Cretaceous Series in West Suffolk and Norfolk," *Quart. Journ. Geol. Soc.*, vol. xliii., pp. 544-598.

3. That the soft grey marl, which lies below this hard bed at Roydon, and which was taken to be part of the Chalk Marl by MR. WHITAKER, is really Gault.

4. That this grey marl extends as far north as Dersingham, where it passes down into a brown and red marly clay (about four feet thick).

The authors infer that this red marly clay is replaced between Dersingham and Heacham by the Red Chalk, and consequently that the latter is the actual stratigraphical equivalent of the Gault. With regard to the fossils they cannot accept the doctrine that those of the latest type or highest range should be relied on as guides to the age of the bed. They regard the so-called chalk species found in the Red Chalk as indicators of a greater depth of water than that of the southern Gault, and point to the occurrence of two of them, viz., *Ostrea curvirostris* and *Terebratulina rigida*, in the Norfolk Gault.

Finally, it may be well to indicate the points on which MESSRS. WHITAKER, JUKES-BROWNE, and HILL are now in agreement. They agree :—

1. That there is no separate representative of the Upper Greensand at Hunstanton, and that the normal succession in Norfolk is a passage from Upper Gault to Chalk Marl.

2. That so far as the fossils are concerned, it is admitted that both Lower and Upper Gault are represented in the Red Rock, and that there is no proof nor even probability that these fossils are derived.

3. That since a large part of the southern Upper Greensand is merely a sandy facies of the Upper Gault those are right who have considered both Gault and Upper Greensand to be represented in the Red Rock.

4. That the Red Chalk has yielded some species which occur elsewhere in the Chalk and not in the Gault, and that the presence of these species is a fact to be accounted for.

5. That so far as Cephalopoda are concerned, the species found in the Red Chalk are those of the Gault, none of those which are specially characteristic of the Lower Chalk having yet been found.

MR. WHITAKER differs from the other two in believing that the Red Chalk includes a Chalk Marl element.

In the detailed description it will be convenient to take first the southern tract in which marly Gault occurs, and then the northern one where Red Chalk is found. A. J. J.-B.

SOUTHERN AREA.

GAULT (MARL AND CLAY).

Main Mass.

Where the outcrop enters the district, near Roydon Row, it is about three quarters of a mile broad. It soon broadens somewhat (except for a covering of Drift sand), at Congham being

over a mile, and at Hillington nearly a mile. Across the Babingley River it gets narrower, however, and soon is but a tenth of a mile wide, by Appleton and West Newton, whence it dies away near Sandringham, where the Red Chalk comes in, and can be shown only by a line on the map.

In this short course the Gault is chiefly marly and of very pale grey, but very pale red or pinkish layers often occur.

The following analyses of various beds of the Gault are taken from the paper by MESSRS. JUKES-BROWNE and HILL, to which frequent reference will be made.*

Analysis, by MR. W. D. SEVERN, of marl from the depth of five feet in the boring at Roydon (see p. 33):—

Residue, insoluble in hydrochloric acid ...	25·55
Carbonate of lime	66·31
Alumina	3·33
Iron (as Fe_2O_3)	·81
Magnesia	·46
Phosphoric acid	trace
Moisture (at 100° C.)	1·85
	98·31

Analysis of the limestone at the base of the marl in the Roydon railway-cutting. By DR. W. JOHNSTONE:—

Insoluble residue (silicates, &c.)	6·64
Carbonate of lime	89·46
Sulphate of lime	1·32
Carbonate of magnesia	·18
Manganese	·4
Alumina	1·4
Peroxide of iron	1·1
Trace of organic matter	
	100·50

Analysis of the red marls, also by DR. JOHNSTONE:—

——	Grimston (just south of district).	Roydon.	Dersingham.
Silica and Silicates	2·26	24·13	25·7
Carbonate of lime	69·5	64·46	64·49
Carbonate of magnesia	·9	·9	1·32
Sulphate of lime	·66	·36	·33
Peroxide of iron	3·4	6·	4·16
Alumina and phosphoric acid ...	1·6	·9	·8
Manganese	trace	trace	trace
Organic matter, &c.	1·34	3·25	3·2
	100·	100·	100·

A comparison of these three analyses, with that of the grey marl, shows that the pink marl "may be regarded as the same

* *Quart. Journ. Geol. Soc.*, vol. xliii., pp. 544, 586, 588 (1887).

marl [as the grey], coloured red by peroxide of iron, the proportions of siliceous matters and carbonate of lime being almost the same, while the proportions of iron and alumina are in an inverse ratio."

At Roydon Row a pond in a field near the back of the Chequers Inn shows gravelly earth at top, and then, at one part, some red marl. There are plentiful signs of the grey marl around here. A ditch at the north-eastern corner of Congham Park (as shown on the old map), and east of the footpath (not on that map) is chiefly in grey clayey marl. Some dark grey clay and red earth end off somewhat strangely, almost as if the wrong way up, the clayey marl passing westward under the red earth, and that under the clay, whereas one would expect them to occur in the reverse order. I felt in doubt whether there was some disturbance, or artificial arrangement.

The Gault was cut into along a ditch running about south and north up the gentle rise a little eastward of Grimston Road Station and about a third of a mile south-east of Roydon Church. At the lower part, to the south, for some way brown sand was the chief thing thrown out; then, northward, where the rise increases a trifle, brown and red earth; then pale bluish-grey chalky earth, with many small *Belemnites*, small hard nodules of race and some phosphatic nodules (apparently at the bottom), decomposed outside to a white surface. At the top were a few small nodules and fragments of hard chalk, which also occur over the ground to the east.

In the next ditch eastward the upper part was clear (1881) and gave a fair section of the marl, not so clear down the slope (south) but about the middle clear for a bit, the following section being then seen :—

Pale-grey clayey marl, passing down into the next.
Brown marl, with red in the lower part, a foot or more.
Grey clay, like ordinary Gault, proved to a depth of 2 feet by boring.

Possibly the beds may rise slightly at this spot, as the marl seems to go some way farther south.

Grey marl was shown along the road over a third of a mile east of Roydon Church and pinkish marl in a pond by a cottage north-eastward.

Just south of the southern end of the cutting about a third of a mile north-eastward of Grimston Road Station I dug in ditches crossed by the line and found a little whitish clayey marl, with a little red earth below, and slightly lower a small phosphatic nodule in clayey earth.

The following account of the cutting is taken from the paper already mentioned* :—"Entering from the southern end, a dark grey calcareous clay is seen for about 50 yards. Some thirty yards south of the bridge which spans the centre of the cutting this clay is seen to be overlain by a bed of hard, bluish-grey rock, 8 or 10 inches thick. Two feet above this bed, and extending for almost the entire length of the cutting from this point to the north, rather more than a foot of the clay is coloured a bright reddish-pink. This band is divided in places by uncoloured material. North of the bridge a second bed of pale yellowish-grey rock, about 8 inches thick, is seen above the red band, separated from it by a few inches of marly clay. The lower of these hard beds proved fossiliferous, the most abundant form being *Inoceramus concentricus;* associated with it were *Inoceramus sulcatus*, *Ammonites lautus*, and *A. rostratus*. The upper bed appeared to contain few fossils. *Inoc. concentricus* occurred sparingly." Above this upper bed there is pale grey marl containing small *Belemnites*.

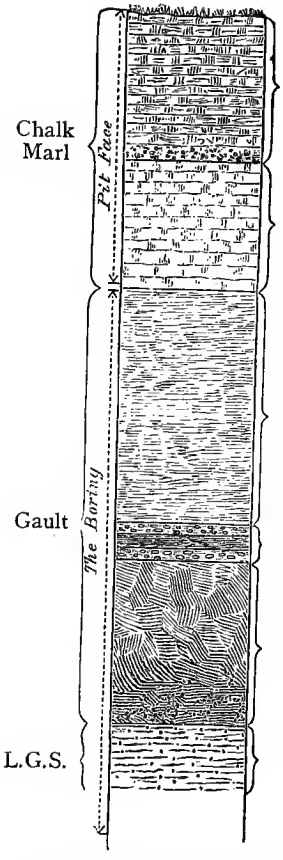
To the north of this cutting there is a low hill capped by an outlier of Chalk, which is exposed in a small pit, and in order to ascertain the full thickness of the Gault here the authors of the paper above quoted had a boring made in the pit. By digging it was found that the hard creamy-white limestone which forms the basal bed of the Chalk Marl passes down into a grey clayey marl like that in the upper part of the railway-cutting; the change is a rapid one and the passage-bed consists of lumps or lenticular

* *Quart. Journ. Geol. Soc.*, vol. xliii., p. 551.

layers of the hard limestone separated by marly material. The complete section here as partly seen in the pit and partly obtained by boring is shown in the annexed diagram for the use of which we are indebted to the Council of the Geological Society :—

*Figure 1. Section near Roydon.** (JUKES-BROWNE and W. HILL.)

Scale, $\frac{1}{3}$ inch to a foot.



	Feet.
Pit.	
Soil	1
Hard, greyish, gritty chalk, including many green-coated nodules at its base (*Inoceramus*-bed)	6
Very hard, creamy-white limestone becoming rather yellower toward the base	5½
Boring.	
Rather tough, grey argillaceous marl with *Belemnites*	10
Yellowish or tawny marly clay, one drawing of the auger (5 inches) being markedly red, the rest stained and blotched with red	1¾
Bluish-grey clay becoming darker below, sandy and almost black at the base	7
Brown sand, proved to...	3¼
	34½

No hard beds were noted in boring, but subsequent examination of the cores showed that hard material had been passed through, and apparently just beneath the yellow and red marl.

The grey marl has been seen in places northward and south-eastward of Congham Hall, and pink marl a little west of Hillington Railway Station.

The small outcrop of marl in the gravel tract W.N.W. seems almost to abut against the Lower Greensand on the other side of the stream, and there may, perhaps, be a small fault here, masked by the gravel.

Grey marl was seen, just above the outcrop of the Lower Greensand by the lane about a mile a little S. of W. from Flitcham Church, and pink marl a little northward of Appleton Church.

The springs in Denbeck Wood, eastward of Appleton, which supply Sandringham House with water, are thrown out at the junction of the Chalk and the marl. Near Sandringham I have seen marl in places. By the side of the lane a little eastward of the Home Farm it was grey and partly

* From *Quart. Journ. Geol. Soc.*, vol. xliii. p. 550.

reddish, this being probably referred to later by MESSRS. JUKES-BROWNE and HILL as "just east of the [kitchen-] gardens." They add: "At a subsequent visit this exposure was covered up, but red clayey earth was seen just above the outcrop of the Carstone around some young trees which had just been planted."* Light-coloured marl seems to have been turned out at the Gasworks (touching the Home Farm on the north). Pink marl occurs in the higher part of the kitchen-garden, and again north-westward near the main road, which does not now run as shown on the old map, but more to the east.

Just northward of this the outcrop seems to cease, at all events it gets untraceable, unless as a mere line, but MESSRS. JUKES-BROWNE and HILL have established the presence of the Gault a mile farther to the north, by means of a boring in the chalk-pit about half a mile north-eastward of Dersingham Church. In this boring marly beds, about 7 feet thick, were found between the Chalk and the Carstone, the upper 2 feet being light grey, the remainder yellow, red, and brown, as described farther on (p. 52). Even this, however, can hardly be taken as "the final thinning-out of the Gault clay," for that probably occurs somewhere between Dersingham and Shernborne or Ingoldisthorpe, beyond which part signs of the Red Chalk set in.

Outliers.

Southward of Castle Rising and westward of Roydon there are some outliers, though in all but one case the Gault is more or less hidden by Drift.

An old pit in a field about half a mile south of the castle was mostly overgrown in 1881. On the west there seems to be some Drift, and at the north a little light-coloured sandy Boulder Clay was seen, with rubbly chalk rising up from beneath eastward. At the east this latter is firmer, except for soil and for weathering in the top part, and the upper part of this firmer chalk contains a harder greyer flaggy layer, seen only at one spot. The bottom of the pit showed signs of the pale pinkish marl, and in the lowest part was a small pond; so that the pit goes through to Gault.

The above agrees with what was seen in another still more obscure ploughed-over pit about a quarter of a mile westward, which showed white and pale pinkish marl.

Marl was also seen about a third of a mile eastward of the first pit.

There is a very small outlier about half a mile south-east of the castle. An old pit here had its highest (southern) part hidden; but there seemed to be a little Boulder Clay (unmappable) at top. The lower part was in marl, with some traces of pinkish beds and also of stone, and there was water at the bottom.

An old pit about two thirds of a mile west of Roydon Hall showed, on the east, a little whitish chalky Boulder Clay over chalky earth (? decomposed and partly reconstructed chalk), whilst on the north whitish marl was seen to rise nearly to the surface, capped by a little of the Boulder Clay, the top part of the marl having a pale pinkish tint. The lower part was hidden by fallen earth. The bottom was wet, and with a pond. I dug at one place into grey clay, and at another, where ploughed, found a little red earth.

A small pit at the northern edge of Roydon Common, less than a mile W.S.W. of the Church, gave a like section, there being a little Boulder Clay over reconstructed (?) chalk, and whitish marl (with pieces of stone). There was water at the bottom, and it looked as if the marl is either faulted down or comes on very irregularly against the Lower Greensand, just south.

About a third of a mile west of Roydon Church, and just north of the sandpit at Roydon Hall, is a small hollow in a field with water at the bottom (Nov., 1881); it is in marl, mostly whitish, but at the base of a deep red. On boring into this for some inches I found dark grey sandy clay. It looks as if there might be a little Boulder Clay at top, but this could hardly be mapped.

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* *Quart. Journ. Geol. Soc.*, vol. xliii., p. 553.

Just eastward, by the hedge of the next field, is a larger shallow pit also showing the pale grey marl, with chalky rubble at top at one part, and at another Boulder Clay. A deeper hole in the pit (? for drainage) gave the following section :—

Gault.	A little of the pale grey marl. Very little of the red bed, which seems to pass down into the next. Clay, the greater part dark grey (but the top discoloured to brown) and the bottom part lighter coloured : a few phosphatic nodules at top and at bottom : in all, about two feet or more : passing down into the next.
Lower Greensand.	Brown sand, which, a few inches down, hardens into a sandstone ; about three feet in all. Brown hard sand, with thin irregular veins of iron-sandstone in the top part ; seen to about three feet.

A third shallow pit, just north, in the corner of the same field, showed only a little rubbly chalk or marl, and apparently some Boulder Clay.

The marl was again seen in another old pit, in the next field to the north, and signs of the like in another, a little higher westward, by the hedge of the same field.

A larger and fresher old pit showed the following beds :—

At east and south.—Boulder Clay.

At north and west.—Rubbly chalk, with whitish marl on west.

The bottom consists largely of the bright red bed, probably with clay below, as water is held.

A hole (? for drainage) showed the top part of the Lower Greensand, as in the section noted above, to the depth of three feet or so.

W. W.

NORTHERN AREA.

RED CHALK.

This red earthy limestone is too thin, and its outcrop, consequently, too narrow, to be shown by more than a line of colour on the map ; a line which marks the base of the Chalk Hills from the west of Shernborne, above the villages of Ingoldisthorpe, Snettisham, and Heacham, to the cliffs near Hunstanton.

As the rock has not been utilised for any commercial purpose the inland exposures are few and small. It was formerly visible in the cartway leading into the chalk-pit south-east of Heacham, but is not seen in the pit itself. It is also exposed at Snettisham (see p. 14) and in a chalk-pit near Hunstanton Station, but the only good section of it is that in the cliffs to the northward, and it is to this that the following account relates. Near the pier the Red Rock is at the summit of the cliff, but it gradually descends as the cliff trends eastward, till it comes down to the beach near Old Hunstanton.

The Red Rock at Hunstanton is about four feet thick, possibly rather less in places, but it forms a very even and regular, as well as conspicuous, band along the cliff face. It rests evenly upon the surface of the Carstone, without any signs of erosion beyond the presence in its lower portion of numerous quartz-grains, large and small, like those which compose the underlying sandstone.

It forms a single massive bed, not laminated nor divisible into separate layers, but at the same time it is by no means of homogeneous composition throughout. Its basal portion is softer and less calcareous than the rest, being also much more sandy, and of a deep brick-red colour. The central part of the rock (from 20

to 24 inches) is a dark red, rough and nodular limestone, with few large quartz-grains, but containing many fossils. The highest part, about a foot thick, is a hard light red or pink limestone, mottled with white, and is probably more calcareous than the rest.

The upper surface of the red limestone is a marked plane of division, and the rock is separated from the overlying chalk by an irregular seam of dark red ferruginous earth, which swells out here and there, and appears to fill spaces caused by inequalities in the under surface of the Chalk.

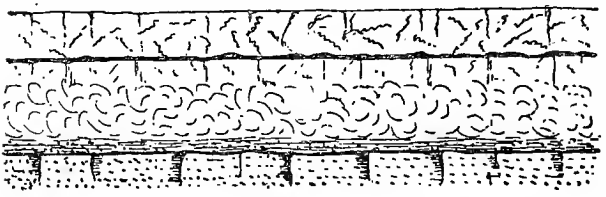


Figure 2. Diagram to show the structure and relations of the Red Chalk at Hunstanton. (JUKES-BROWNE.)

Some observers have thought that the different portions of the Red Rock contained a different set of fossils, but, so far as our experience goes, the difference is chiefly a matter of relative abundance, *Belemnites minimus* and *Terebratula biplicata* being most abundant in the lower part, while the highest part yields many specimens of *Inocerami* and of *Exogyra haliotoidea.*

The higher part of the Red Chalk also exhibits some of the cylindrical and branching bodies which have been regarded as parts of a Sponge, and named *Spongia paradoxica.* Portions, however, that have been sliced and examined under a microscope show no sponge-structure nor any other kind of organic structure. PROF. HUGHES has discussed these curious bodies, and concludes that they are probably "merely concretions, owing their symmetry of form and regularity of arrangement to rock structure, which is more obvious in the cliff than in hand specimens."* They are still more abundant in the overlying bed, to which the name "Sponge Bed" has in consequence been given by some writers.

The seam of dark red earth is in places worked out by the waves, and hollow spaces are left in consequence. In some of these hollows brown sand has been found, and it has been supposed by some observers that this sand was deposited there with the red earth, but we think the sand has been washed up and driven in by the sea-waves.

Structure of Red Chalk.

MR. W. HILL has kindly communicated the following account of the minute structure of the Red Chalk of Hunstanton from specimens collected by himself:—

* *Quart. Journ. Geol. Soc.*, vol. xl., p. 276 (1884).

My slides from the base of the Red Chalk are roughly cut. I have, however, no doubt from that which I can see that there is a greater amount of inorganic material here than in the higher parts of the rock. The grains of quartz sand are certainly more abundant, while the impression conveyed by such parts of the slides as one can see through is that organisms of sorts are less common. There do not appear to be any definite particles or aggregations of peroxide of iron, and presumably the whole of this part of the rock is uniformly stained with this material.

Thin sections of the upper and middle part of the red chalk show that the matrix of this rock consists largely of calcareous material in the condition of minute particles of crystalline calcite. Along the edge of a section, or where the section is thin, the particles of calcite seem to be clear and colourless, but where the section gradually thickens a red tint becomes more and more apparent, but it does not seem possible to separate, optically, any material from which the colour might be derived. There are spaces, small in area, not very sharply defined, where the colour is darker and the rock more opaque, and not infrequently the cells of foraminifera and spicular canals seem filled with dark reddish matter. In this part of the rock the proportion of fine inorganic matter must be small.

The mass of the rock is full of angular, sub-angular, and rounded grains of quartz, many large enough to be detected by the naked eye; also many grains which from their rounded outline seem to be glauconite, but except in a few instances this clear green mineral seems to have become a dark brown and almost opaque substance.

Foraminifera are common and "spheres" abundant. The infilling material of the foraminiferal cells is generally granular crystalline calcite without colour, but examples occur in all slides showing the infilling material in gradations from white crystals to a colour of darker red than the surrounding matrix. Sponge-spicules occur, and shell-fragments are present, but are not abundant.

MR. HILL was specially asked to compare the structure of the Red Chalk of Hunstanton with that of hard beds in the Chalk formation, and on this point he writes as follows:—"I should regard the upper two thirds of the bed as, lithologically, a real chalk. The particles of its matrix do not differ from those of certain other chalks, though they are coarser than in some. In this respect the matrix of different beds of chalk show a gradation which appears to correspond with the degree of induration and crystallization of the rock; the particles being most minute in the softer chalks and marls, and largest in the semi-crystalline beds like Chalk Rock. In the Red Chalk the crystallization of the particles has not gone far enough for the matrix to be described as granular crystalline calcite, but the particles are strongly coherent."

"A slide of this Red Chalk has a general character of its own, and will not compare with any definite horizon in the Chalk above it, but it is not easy to pick out particulars in which it differs. I am inclined to think, however, that on the whole it contains more well-preserved and clearly outlined tests of Foraminifera than most samples of chalk, and in this respect it resembles Chalk Rock; but very possibly the species present in the two rocks are different. Calcareous spheres are abundant, but not more so than in some parts of the lower chalk."

Analyses.

Many analyses of the Red Chalk of Hunstanton have been made at different times, and it will be well to reproduce them, because, as might be expected, the different portions of the rock differ somewhat in chemical composition.

The earliest analysis which has come under our notice was made by MR. RICKARD, and published by the REV. T. WILTSHIRE in 1859,* this being as follows :—

Carbonate of lime, with a little alumina	82·3
Peroxide of iron	6·4
Silica	11·3
	100·

A little later a more complete analysis of the rock was made by MR. R. C. CLAPHAM, and published in 1862.† With this may be grouped another, made by MR. F. SUTTON, a few years later.‡

	Clapham.	*Sutton.*
Carbonate of lime	80·04 ...	80·1
Sulphate of lime	·1 ...	trace
Peroxide of iron	9·6 ...	8·5
Alumina	1·42 ...	1·5
Silica	9·28 ...	9·4
Manganese	trace ...	—
Magnesia	— ...	trace
Organic matter	— ...	8·5 (? 5)
	100·44 ...	108· (? 100)

MR. W. M. LUPTON noted, in 1863, that the peroxide of iron varies from 9 to 17 per cent. ; but analyses made by PROF. A. H. CHURCH,§ and published the same year, show a much higher percentage for parts of the rock. He says "the hard nodules [*i.e.*, the darker red nodular portions of the rock] contained as much as from 31·2 to 36·9 per cent. of anhydrous sesquioxide of iron, while the pale red varieties . . . contained no more than from 12·73 to 4·1." The following are the details of the analyses referred to, the first and second columns showing the composition of the darker nodular samples, and the third that of the lighter red part.

Carbonate of calcium	44·75	50·07	65·03
Sesquioxide of iron	36·9	31·2	12·73
Alumina	·18	not determined	
Silica	·72	,, ,,	2·21
Sulphate of calcium	·04	·075	·15
Carbonate of magnesium ...	·35		
Manganese	trace		
Chloride of sodium	·03	not determined	
Water	16·41		
Other substances and loss ...	·62		
	100·		

The first analysis "includes all the chief constituents, while the others refer only to the sulphate of calcium, the carbonate of calcium, and the sesquioxide of iron."

* *Geologist*, vol. ii., p. 260 (1859).
† *Chem. News*, No. 160, p. 313 (1862), and *Geologist*, vol. vi., p. 29 (1863).
‡ *Geol. Mag.*, vol. iii., p. 43 (1866), from *Norwich Mercury*, 9th Dec., 1865.
§ *Quart. Journ. Chem. Soc.*, n. ser., vol. i., pp. 79-86 (1863).

PROF. CHURCH remarks that the large quantity of water may result from the season (April) in which the specimens were got, but some of this water was not removed by an exposure to a high temperature.

The following analysis of red clay from the Red Chalk of Hunstanton has also been made by PROF. CHURCH,* who remarks that this was "the finer portion of the undissolved residue . . . separated from the siliceous fragments which accompanied it," which "amounted, on the average, when air-dried, to 9·3 per cent. of the weight of the chalk taken, but some dark samples furnished higher percentages." The chalk analysed was "the paler and more ordinary variety," as distinguished from the dark nodules.

	Air-dried.	Dried at 100 C.	Ignited.
Water	14·73	7·54	—
Silica	52·87	57·33	62·01
Ferric Oxide (Fe_2O_3)	12·81	13·89	15·02
Alumina	15·65	16·97	18·36
Magnesia (MgO)	2·65	2·87	3·11
Potash (K_2O)	1·33	1·45	1·56
	100·04	100·05	100·06

The most recent analyses known to us are some by DR. W. JOHNSTONE, who took a series of samples from all the beds in the cliff at Hunstanton, and analysed each carefully and completely. He has not published these in detail, but placed one of the highest pink portion at the disposal of MESSRS. JUKES-BROWNE and HILL, who published a summary of it, as below:—

Silica and insoluble residue	7·50
Carbonate of Lime	83·81
Alumina	1·67
Peroxide of iron	5·72
Manganese	·58
Magnesia	·62
	99·90

DR. JOHNSTONE also analysed a sample of the hard red nodular lumps taken from the lower and redder portion of the Red Rock with the following result:—

Lime	22·839
Carbonic Acid	18·922
Alumina (Al_2O_3)	1·214
Phosphoric Acid (P_2O_5)	·336
Peroxide of Iron (Fe_2O_3)	42·683
Oxide of Manganese (MnO)	·758
Oxide of Copper (CnO)	.034
Trioxide of Arsenic (As_2O_3)	1·286
Sulphuric Acid (SO_3)...	·342
Chlorine	1·023
Silica	8·425
Magnesia	·708
Water	·120
Organic Matter	·323
Alkalies	·951
	99·964

* *Chem. News*, vol. xxxi., no. 806, p. 199 (1875).

Assuming that ·284 of the Lime is combined with the Phosphoric Acid, and that all the rest is combined with Carbonic Acid to form Carbonate of Lime, and that the Alkalies are in the state of Chlorides, we have the following composition :—

Carbonate of Lime	40·327
Carbonate of Magnesia	1·486
Phosphate of Lime	·620
Alumina	1·214
Peroxide of Iron	42·683
Oxides of Manganese, Copper, and Arsenic ...	2·078
Silica and Clay	8·425
Chlorides of Soda and Potash...	1·974
Water and Organic Matter	·443
	99·250

The combination of the Sulphuric Acid is uncertain and is omitted.

Summarising the results of the preceding analyses it would appear that the rock contains a large amount of peroxide of iron, especially in the hard nodules of the lower part which contain as much as from 37 to 42 per cent. Ordinary samples of the central part appear to have from 8 to 10 per cent., with 10 or 11 per cent. of siliceous matter and 80 per cent. of carbonate of lime. The most calcareous and lighter-coloured portion consists roughly of nearly 84 per cent. of carbonate of lime with about 6 per cent. of iron and manganese, and 7 or 8 per cent. of siliceous matter.

Combining the results obtained by chemical analysis with those derived from a microscopical study of the rock we seem justified in concluding that the Red Chalk of Hunstanton is a highly calcareous rock resembling in all essential particulars the harder kinds of chalk. MR. WHITAKER has maintained that the rock is really Chalk, and he is so far right that it may certainly be regarded as, lithologically, a kind of chalk, but this in no way affects the determination of its age, since chalk is merely a variety of limestone, and may be of any age.

With respect to its colouring it is not easy to say whether the red ferruginous matter was deposited with the chalky material on the sea-floor, or whether it has been infiltrated subsequently and replaces some of the original carbonate of lime.

It has generally been supposed that the red colour was merely a stain, and MR. HILL'S description of his slides shows that for large portions of the rock this is the case. But a very small amount of ferric oxide is sufficient to give a red colour to a rock, 2 or 3 per cent. being enough, and the quantity in some parts of the Hunstanton rock seems from the analysis to be so large that it must be regarded either as an original constituent or as a mineral deposit subsequently introduced.

If the Red Chalk occurred only where the bed was underlain by Carstone, it might be thought that the colour was derived from that rock ; but this can hardly be the case, for the bed is still red in those parts of Yorkshire where it lies on the Jurassic or Speeton clays. Moreover, at Speeton its equivalent is a red marl 30 feet thick.

It has been suggested that the ferric oxide has come from the thin layer of peroxide or hematite which overlies the Red Chalk at Hunstanton, but no such layer has been observed in Lincolnshire or Yorkshire, and in Lincolnshire there is often a more gradual passage from red to white chalk than there is at Hunstanton. Further, the formation of the layer of peroxide at Hunstanton would still remain to be accounted for, and the whole matter requires more detailed investigation than has hitherto been made.

Fossils of the Hunstanton Red Rock.

The following is a list of the fossils of the Red Rock of this locality, as complete as we have been able to make it.

The list of *Foraminifera* is taken from the paper by MESSRS. BURROWS, SHERBORN, and BAILEY in *Journ. Roy. Micr. Soc.*, 1890, p. 549; with corrections with which we have been favoured by MR. F. CHAPMAN.

The Polyzoa are taken from papers by MR. G. R. VINE in Brit. Ass. Rep. for 1884 and 1892, in *Quart. Journ. Geol. Soc.*, vol. xlvi., p. 454 (1890), and in *Proc. Yorksh. Geol. Soc.*, vols. xi. and xii. (1891-92).

The lists of other classes are taken partly from that in the paper by MR. WHITAKER, with additions and corrections by MR. JUKES-BROWNE from notes of the collections in the Woodwardian Museum, Cambridge, and elsewhere.

The occurrence of the same species in Gault, Cambridge Greensand, and Lower Chalk is shown in the parallel columns. Excluding Foraminifera and Polyzoa, there are about 90 species and well-marked varieties; of these 14 are not yet known out of the Red Chalk, thus reducing the number for comparison to 76. So far as the range of these 76 species is known 47 of them occur in English Gault, and 41 of them as derived fossils in the Cambridge Greensand, while only 39 occur in Lower Chalk. Two others, however, occur in the sandy matrix of the Cambridge Greensand which may be reckoned as Chalk species, and bring up the number to 41. If, however, we look to those which are exclusively Gault or Chalk species, we find 26 of the former and only 12 of the latter; while if we take the Cephalopoda alone as guides, all of them are characteristic Gault species, only one (*Am. planulatus*) ranging up into the Lower Chalk.

Fossils from the Red Chalk.

Red Chalk.	Gault.	Cambridge Greensand.	Lower Chalk.
Foraminifera.			
Anomalina ammonoides, *Reuss*	×	×	×
„ grosserugosa, *Grünb.*	—	×	
Bulimina Presslyi, *Reuss*	×	—	×
Cristellaria crepidula, *F. and M.*	×		
„ italica, *Defr.*	×		
„ rotulata, *Lam.*	×	×	×
Dentalina communis, *d'Orb.*	×	×	×
Globigerina bulloides, *d'Orb.*	×	×	×
„ cretacea, *d'Orb.*	×	×	×
„ linnæana, *d'Orb.*			
Lagena apiculata, *Reuss*	×		
„ lævis, *Mont.*	×		
Lingulina carinata, *d'Orb.*	×		
Nodosaria calomorpha, *Rss.*			
„ limbata, *d'Orb.*			
Polymorphina sp.			
Textularia pygmæa, *Reuss*	×	×	×
„ trochus, *d'Orb.*	×	×	×
„ turris, *d'Orb.*	×	×	×
Trochammina			
Spongida.			
Chenendopora expansa, *Benett.*			
Plocoscyphia labrosa, *T. Smith*	—	—	×
„ labyrinthica, *Mant.*	—	—	×
Coscinopora quincuncialis, *T. Smith*	—	×	×
Ventriculites tesselatus, *T. Smith*	—	×	
Actinozoa.			
Cyclolites polymorpha, *Goldf.*			
Micrabacia coronula, *Goldf.*	—	—	×
Podoseris elongata, *Dunc.*			
„ mammilliformis, *Dunc.*			
Echinodermata.			
Cidaris dissimilis (?), *Forbes*	—	—	×
„ gaultina, *Forbes*	×	×	
„ vesiculosa, *Goldf.*	—	—	×
„ new sp. (spines)			
Echinoconus (?) sp.			
Holaster lævis (?), *Deluc.*	×	×	×
„ suborbicularis (?), *Defr.*	—	—	?
Peltastes Wiltshirei, *Seeley*			
Pentacrinus Fittoni, *Austin*	×	×	×
Pseudodiadema Brongniarti, *Wright, non Ag.*...	—	—	×
„ ornatum, *Goldf.* ...	×	×	×
„ var. scriptum, *Seeley*	—	×	
Torynocrinus rugosus, *Seeley*			
„ brevis, *Seeley*			

Red Chalk.	Gault.	Cambridge Greensand.	Lower Chalk.
Annelida.			
Serpula antiquata, *Sby.*	×	×	×
„ articulata (?), *Sow.*	×	—	×
„ cristata, *Dry.*			
„ depressa, *Goldf.*			
„ rustica, *Sby.*			
„ (Vermicularia) umbonata, *Mant.* ...	—	—	×
Crustacea.			
Pollicipes unguis, *Sow.*	×	—	×
? Entomostraca			
Polyzoa.			
Apsendesia collis, *d'Orb*			
„ papyracea, *d'Orb*			
Ceriopora micropora (?), *Goldf.*			
Diastopora (Berenicea) contracta, *Sceley* ...			
„ fæcunda, *Vine*	—	×	
„ hunstantonensis, *Vine*			
„ Jessoni, *Vine*			
„ papillosa, *Reuss*			
„ regularis, *d'Orb.*	—	—	×
„ radians, *Novak*			
„ (Cellulipora) sulcata, *Seeley* ...			
Entalophora proboscidea, *Edw.*	—	×	
Hippothoa (?) simplex, *d'Orb.* (? Membranipora)			
Heteropora cryptopora, *Goldf*			
„ irregularis, *d'Orb*			
Membranipora elliptica, *Novak*			
„ fragilis, *d'Orb*			
„ gaultina, *Vine*	×		
„ obliqua, *d'Orb.*			
Multicriseis variabilis, *d'Orb.*			
„ mammillata, *d'Orb*			
Proboscina angustata, *d'Orb.*	—	×	
„ dilatata, *d'Orb.*	—	×	
„ bohemica, *Novak*			
„ gigantopora, *Vine*	—	×	
„ gracilis, *Reuss*, var. Reussi... ...			
„ hunstantonensis, *Vine*			
irregularis, *Vine*			
inornata, *Vine*			
„ Jessoni, *Vine*			
„ ramosa, *d'Orb.*	—	×	×
„ rugosa (?), *d'Orb.*			
„ subelegans, *d'Orb.*			
„ toucasiana, *d'Orb*			
uberrima, *d'Orb.*			
Reptomulticava collis, *d'Orb.*			
„ favus, *Seeley*			
„ mammilla, *Reuss*			
„ simplex, *d'Orb.*			

Red Chalk.	Gault.	Cambridge Greensand.	Lower Chalk.
Polyzoa—(continued).			
Stomatopora divaricata, *Roem.*			
„ gracilis, *Edw.*	—	×	×
„ granulata, *Edw.*			
„ „ var. incrassata, *d'Orb.*			
„ linearis, *d'Orb.*	—	×	
„ longiscata, *d'Orb.*	—	—	×
„ ramea, *Blainv.*	—	—	×
„ regulosa, *Reuss.*			
„ variabilis, *Vine*			
Truncatula subpinnata, *d'Orb.*			
Unicavea collis, *d'Orb.*			
Unitubigera papyracea, *d'Orb.* (see Apsendesia)			
Zonopora irregularis, *d'Orb.*			
„ undata (?), *d'Orb.*			
„ variabilis (?), *d'Orb.*			
Brachiopoda.			
Kingena lima, *Defr.*	×	×	×
Rhynchonella Cuvieri (?), *d'Orb.*	—	—	×
* „ lineolata, *Phil.*			
„ sulcata, *Park*	×	×	
Terebratula biplicata, *Sow.*	×	×	×
„ „ var. dutempleana, *d'Orb.*	×	×	
„ capillata, *d'Arch.*	—	—	×
„ semiglobosa, *Sow.*	—	—	×
„ sulcifera, *Morris*	—	—	×
*Terebratulina triangularis, *Eth.*		×	
Lamellibranchiata.			
Anomia sp.			
Avicula gryphæoides, *Sow.*	×	×	×
Exogyra conica, *Sow.*	×	×	×
„ haliotoidea, *Sow.*	×	×	×
„ „ var. rauliniana, *d'Orb.* ...	×	×	
Hinnites Etheridgei, *Seeley*, MS.			
„ Salteri, *Seeley*, MS.			
„ Studeri (?), *Pict. and Roux*	—	×	
„ trilinearis, *Seeley*	×	×	
Inoceramus concentricus, *Park*	×	×	
„ Cripsi, *Mant.*	?		
„ sulcatus, *Sow*	×	?	
„ tenuis, *Mant.*	×		
Lima globosa, *Sow*	×	×	×
„ itieriana (?), *P. and Roux.*	×	×	
Ostrea curvirostris, *Nilss.*	×	—	×
„ frons, *Park*	×	×	×
„ normaniana, *d'Orb.*	—	—	×
„ vesicularis, *Lam.*	×	×	×
Perna lissa, *Seeley*			
„ transversa, *Seeley*			

* Occur in Cambridge Greensand, but not as derived fossils.

Red Chalk.	Gault.	Cambridge Greensand.	Lower Chalk.
Lamellibranchiata—(continued).			
Pecten Beaveri, *Sow.*	×	—	×
„ elongatus (?), *Lam.*	—	—	×
„ orbicularis, *Sow.*	×	×	×
*Plicatula minuta, *Seeley*			
„ pectinoides, *Sow.*	×	×	×
„ sigillina, *Woodw.*	×	×	×
Spondylus gibbosus, *d'Orb.*	×	×	
„ striatus, *Sow.*	—	—	×
Trigonia scapha, *Ag.* (= T. hunstantonensis, *Seeley*)			
Gasteropoda.			
Aporrhais marginata, *Sow.*	×	×	
Cerithium ornatissimum, *Desh.*	×	—	×
Natica Genti, *Sow.* (= gaultina, *d'Orb.*) ...	×	×	
Pleurotomaria sp.			
Cephalopoda.			
Ammonites (Hoplites) auritus, *Sow.*	×	×	
„ (Desmoceras) Beudanti, *Brong.* ...	×		
„ (Hoplites) Guersanti, *d'Orb.* ...	×	×	
„ („) interruptus, *Brug.* ...	×		
„ („) lautus, *Sow.*	×		
„ („ ?) ochetonotus, *Seeley* ...	×		
„ (Desmoceras) planulatus, *Sow.* ...	×	×	×
„ (Schloenbachia) rostratus, *Sow.* ...	×	×	
„ (Desmoceras) sphærotus, *Seeley* ...			
„ (Hoplites) splendens, *Sow.* ...	×	×	
„ („) tuberculatus, *Sow.*	×		
Belemnites attenuatus, *Sow.*	×	×	
„ minimus, *List*	×	×	
Crioceras occultus, *Seeley*			
Nautilus albensis, *d'Orb.*	×	×	
„ hunstantonensis, *Foord and Crick* ...			
„ simplex (?), *Sow.*			
Pisces.			
Edaphodon Sedgwickii, *Ag.*	×	×	
Drepaniphorus canaliculatus, *Eg.*	—	×	×
Notidanus sp.			
Lamna appendiculata, *Ag.*	×	×	×
Reptilia.			
Ichthyosaurus campylodon, *Carter.*	×	×	×
Plesiosaurus latispinus (?), *Owen*	—	×	

A. J. J.-B.

* Occurs in Cambridge Greensand, but not as a derived fossil.

CHAPTER 4. LOWER CHALK.

General Remarks.

It is only recently (1887) that the Lower Chalk of Norfolk has been brought into correlation with that of more southern counties. The hard chalk of Hunstanton cliff had been described by many writers, and attempts have been made to correlate certain parts of it with known horizons,* but the beds there exposed are so different from those which occupy the same stratigraphical position near Cambridge that, until the intervening area had been carefully examined and some idea had been obtained of the manner in which the one lithological type or facies passed into the other, no correlation of the several horizons could be more than suggestive.

The examination of the Lower Chalk along the tract between Newmarket and Narborough was made by the present writer and Mr. W. Hill in 1886, and important clues were obtained at Mildenhall, Stoke Ferry, Shouldham, and Marham. In the same year Mr. Whitaker accompanied Mr. Hill in a traverse from Narborough to Hunstanton, for the purpose of continuing the work. One important result of this traverse was the identification of the representative of the Totternhoe Stone in a series of quarries from Sandringham to Hunstanton; another was the tracing of the Melbourn Rock, which had been recognised to the southward, and this fixed the upper limit of the Lower Chalk.

Mr. Hill paid several subsequent visits to this part of Norfolk, and to him indeed is due the chief credit of establishing zonal divisions of the Lower Chalk in that area on a sure basis, for he not only measured the section in every quarry, but collected the fossils from each horizon, as well as a series of rock-specimens which he sliced and examined under the microscope. The results of our joint work were published by the Geological Society, and the following account is drawn up from the printed paper† :—

As elsewhere in England the Lower Chalk is divisable into two broad zones: (1) that of *Ammonites varians* or *Rhynchonella Martini*, and (2) that of *Ammonites rotomagensis* or *Holaster subglobosus*. The former is the equivalent of the Chalk Marl of the southern counties, but in Norfolk it consists entirely of hard chalk, having at its base the hard whitish rock or so-called "Sponge-bed" of the Hunstanton cliff, above which comes the grey shelly band, which has been termed the "Inoceramus bed." The Totternhoe Stone forms the base of the higher zone, and is a bed of hard grey chalk with a basement layer of rough green-coated nodules. Above this horizon is thin-bedded platy chalk, lighter coloured above, and passing up into hard white rock in which fossils are scarce.

* Barrois, "Recherches sur le Terr. Crét. Sup.," p. 156, and Jukes-Browne, *Geol. Mag.*, dec. ii., vol. vii., p. 255 (1880).

† *Quart. Journ. Geol. Soc.*, vol. xliii., p. 544.

The subzone of *Belemnitella* [Actinocamax] *plena*, which forms a thin band at the top of the Lower Chalk in other parts of England, appears to be absent in this part of Norfolk.

The thickness of the Chalk Marl varies from 13 to 18 feet, that of the Totternhoe Stone is always from 2 to 2½ feet, that of the upper beds is from 35 to 40 feet, so that the total thickness of the Lower Chalk in this part of Norfolk is only 55 feet, as compared with a thickness of 160 or 170 feet in Cambridgeshire. This reduction seems to be due chiefly to the diminution in the amount of fine silt or inorganic material, and the consequent concentration of the shelly and calcareous matter, so that all the beds become more purely calcareous as they are followed to the northward.

Several analyses have been made of the lower beds of the Lower Chalk in Hunstanton Cliff. The two earliest that have come under our notice are the following.

An analysis of the White Chalk of Hunstanton Cliff was made in 1862 by MR. R. C. CLAPHAM,* and another, of a specimen taken from immediately above the Red Chalk, by MR. F. SUTTON in 1865.† These may be combined, as below :—

	Clapham.	*Sutton.*
Carbonate of lime	95·8	96·2
Peroxide of iron	1·08	1·1
Alumina	·52	·6
Magnesia	·48	—
Silica	2·28	2·01
Manganese	·11	—
Organic matter	—	·09
	100·27	100·

The following analyses of the basal bed of the Chalk at Hunstanton were made by DR. W. JOHNSTONE, and are taken from a paper by PROF. HUGHES‡ :—

——	Sponge-bed.	Sponge-bed, just above the Red Chalk.	Spongia paradoxica.
Lime	53·23	52·05	52·4
Carbonic anhydride	42·295	41·456	41·283
Alumina	·353	trace	·477
Phosphoric anhydride	·289	·268	·338
Sesquioxide of iron	·325	·635	·213
Oxide of manganese	—	trace	trace
Magnesia	·748	·773	·81
Sulphuric acid	trace	trace	trace
Chloride of sodium	trace	trace	trace
Silica	3·17	5·025	5·057
Organic matter	trace	trace	trace
	100·41	100·207	100·578

* *Chem. News*, no. 160. p. 313, and *Geologist*, vol. vi., p. 29 (1863).
† *Geol. Mag.*, vol. iii., p. 43 (1866), from *Norwich Mercury*, 9 Dec., 1865.
‡ *Quart. Journ. Geol. Soc.*, vol. l., p. 278 (1884).

The first of these indicates a proportion of about 95 per cent. of carbonate of lime, the other two of about 93 per cent., the difference being due to a somewhat larger amount of silica in the second and third samples than in the first.

The following analysis of a sample of the Inoceramus Bed at Hunstanton was made by DR. W. JOHNSTONE (*Quart. Journ. Geol. Soc.*, vol. xliii., p. 587):—

Lime	51·50
Carbonic acid (anhydride)	40·54
Phosphoric anhydride	·16
Sulphuric acid	·09
Alumina (Al_2O_3)	·35
Peroxide of iron (Fe_2O_3)	·50
Manganese	·47
Magnesia	·25
Sodium chloride	·75
Silica (insoluble)	3·38
Moisture and organic matter	1·40
	99·39

Neglecting the Sulphuric Acid and assuming that all the Lime is combined with the Carbonic and Phosphoric Acids the composition of the rock may be stated as below:—

Carbonate of lime	91·61
Carbonate of magnesia	·50
Phosphate of lime (Ca_32PO_4)	·35
Sodium chloride	·75
Oxides of iron and manganese	·97
Silica and clay	3·73
Moisture and organic matter	1·40
	99·31

The following analysis of a sample of the Inoceramus Bed, taken from the pit north-east of Roydon Church, was made by Dr. W. JOHNSTONE*:—

Moisture	·936
Water of combination	·176
Carbonic dioxide	38·650
Sulphuric anhydride	·663
Phosphoric anhydride	2·522
Calcium oxide	47·250
Magnesium oxide	·601
Alumina	trace
Ferrous oxide	1·255
Manganous oxide	trace
Sodium chloride	·058
Insoluble residue	7·554
	99·665

A further analysis of the insoluble part yielded the following result:—

Silica	5·547
Alumina	·900
Ferric oxide	·560
Calcium oxide	·107
Organic matter	·440
	7·554

* See *Proc. Norwich Geol. Soc.*, vol. i., part viii., p. 238 (1884).

The sample is remarkable for containing so much phosphoric anhydride, equivalent to 5·5 per cent. of calcium phosphate. The amount of calcium carbonate would seem to be only 79·84 per cent., but there are some difficulties in reconstructing the mineral composition of the rock from this analysis.

Microscopic Structure.

As might be expected from the preceding description, the successive beds of the Lower Chalk differ considerably in microscopic structure. Moreover, as the Lower Chalk is traced through Norfolk from Stoke Ferry to Hunstanton, certain beds are found to thin out and disappear, so that there is a lateral change in structure, as well as a vertical one. The following account is taken largely from the paper already quoted, supplemented by some further notes supplied by MR. W. HILL.

The glauconitic marl, which has been traced from Stoke Ferry to Shouldham (in Sheet 65), does not appear in the quarry half a mile N.N.E. of Roydon Church.

The bed which directly overlies the Gault at Roydon is a hard creamy-white limestone, the structure of which is comparable to the hard Chalk Marl which overlies the glauconitic basement-bed at Shouldham. Thin slices show that it consists mainly of fine amorphous calcareous dust, through which Foraminifera and calcareous spheres are abundantly scattered, but these enclosures, with a few shell-fragments, hardly form 25 per cent. of the material.

That the so-called "*Sponge Bed*" of Hunstanton is a similar rock will be evident from the following description of two slides by MR. HILL: "The matrix is fine amorphous calcareous material, full of "spheres" and Foraminifera. Compared with the Red Chalk below, it is scarcely so crowded with organisms, and fragments of shell are rather more abundant. No grains of quartz or of glauconite are observable. A slide from the part which immediately overlies the Red Chalk, however, contains a few small grains of sand and glauconite, and also small aggregations of an opaque substance distributed through the mass, which, by direct light, have the rusty appearance of an oxide of iron."

Respecting the *Inoceramus Bed*, the following is quoted from our joint paper*: "In the hard grey chalk above the creamy-white limestone at Roydon, we find the gritty character of the [Chalk] Marl, which we have noted as gradually increasing to the northward, still more marked. Here it closely resembles the Totternhoe Stone in appearance and structure, consisting of about 60 per cent. of coarse, irregularly-sorted shell-fragments,

* *Quart. Journ. Geol. Soc.*, vol. xliii. p. 583.

mostly prisms of *Inoceramus* shells; grains of glauconite are abundant, and the whole is set in a matrix of amorphous calcareous material. The green-coated nodules at its base are not shelly, but agree in character with the underlying limestone." They are probably slightly phosphatic.

Of the *Inoceramus Bed*, as seen at Snettisham, Heacham, and Hunstanton, MR. HILL writes: "The lower part of this bed might be described as a calcareous sand, being almost entirely made up of the prisms and minute broken fragments of *Inoceramus* shells, the interstices being filled with fine calcareous paste. Foraminifera are common, and the specimens are conspicuous for their robustness and large size. Small grains of glauconite are common, but no other mineral can be recognised.

"The grittiness caused by the number of shell-fragments passes away upwards, and the proportion of fine matrix increases. The structure of the basal portion suggests the action of a current which carried away much of the finer material, leaving only the heavier particles and shells."

Totternhoe Stone.—The ordinary Totternhoe Stone, from the outcrops in the counties of Bedford, Hertford, and Cambridge, consists of from 60 to 70 per cent. of shell-fragments which are generally very uniform in size, many glauconite grains which are frequently of large size, and a small percentage of fine quartz-sand, the interstices being filled as usual with fine calcareous matter.

"At Sandringham, Dersingham, and all exposures beyond the massive bedded layer at the top of the hard Chalk Marl possesses the same shelly character as its equivalent in Hertford and Cambridge. Specimens from most of these exposures show some little irregularity in the size of the comminuted fragments of shell, but that from the cliff at Hunstanton is very like the upper part of the stone exposed in the Totternhoe quarries. It must be added, however, that the fine quartz-sand, which at Totternhoe forms a part of its constituent material, is almost absent at Hunstanton. The gradual diminution in the proportion of this can be followed along the line of the outcrop of the Stone."*

The *Grey Chalk* above the Totternhoe Stone differs in having a much larger proportion of fine amorphous matrix with comparatively few shell-fragments and no glauconite. Spheres and Foraminifera occur in moderate numbers.

Details.

The Lower Chalk enters the district by Roydon, but is there overspread by Drift sand, and the first exposure is in the Hillington pit on the eastern side of the road between that place and Congham. This pit is worked on two levels and the combined section is as follows:—

* *Quart. Journ. Geol. Soc.*, vol. xliii., p. 584.

Upper Level.	Feet.
Soil and chalk rubble	1
Hard, thin-bedded platy chalk, white with yellowish stains, and a thin band of buff marl near the top	19
Lower Level.	
Whitish thin-bedded chalk...	4½
Thin, but persistent layer of buff marl	0
Hard, thick-bedded, whitish chalk	4
Dull, white chalk, in thick beds divided by layers or seams of greenish-grey marl	10
	38½

The whole of this section is evidently above the horizon of the Totternhoe Stone. The lowest beds contain *Holaster subglobosus* and *Discoidea cylindrica*. The overlying whitish chalk is a conspicuous band on account of its massive appearance and smooth, clean fracture ; its structure resembles that which occurs at the summit of the Lower Chalk farther south.* In the platy chalk near the top of the pit, MR. HILL found an echinoderm which appeared to be *Echinoconus subrotundus*, a Middle Chalk species not previously found in the Lower Chalk. There can be no doubt that the section shows the highest part of the Lower Chalk, and it is possible that the marl band near the top is the representative of the Belemnite marls of the southern counties, an horizon which appears to be on the point of thinning out at Marham in the district to the south (Sheet 65).

The large old pit, marked on the map east of West Newton, and just west of the water-tower, showed at the highest part, under the tower, a yellowish nodular layer, six feet or more down, above which the hard, flaggy chalk projected slightly in places.

The old pit, three quarters of a mile north-east of Sandringham, exposes what we take to be the representative of the Totternhoe Stone. The upper part is hidden, but lower down six or seven feet of chalk are seen, the beds being as follows :—

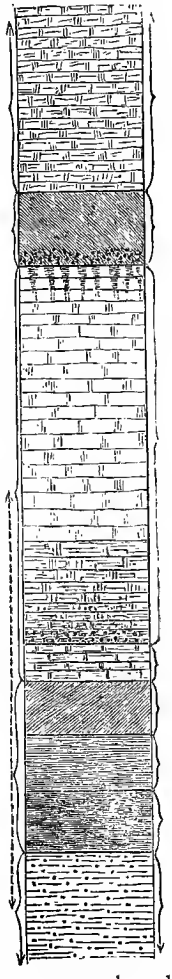
	Feet.
Rather hard dull greyish-white splintery chalk, about	3
Hard grey gritty stone, with many glauconite grains, and some small phosphatic nodules ; a layer of green-coated nodules at the base	2½
Hard cream-white chalk, rather mottled and with few green grains, seen for	1½

A good exposure of the lower part of the Lower Chalk is to be found in the parish pit of Dersingham, about half a mile north-east of the church. The section here was described by DR. BARROIS in 1876,† and he carefully distinguishes a hard bed with nodules at its base, though he did not possess the clue which leads us to regard it as the representative of the Totternhoe Stone. As already mentioned, a boring was made from the floor of this pit to ascertain what lay beneath the hard Chalk Marl. The complete section disclosed by the quarry and the boring is given below :—

* See *Quart. Journ. Geol. Soc.*, vol. xliii., p. 569.
† "Recherches sur le Terr. Crét. sup.," p. 106.

*Figure 3. Section at Dersingham Chalk-pit.** (JUKES-BROWNE and W. HILL.)

Scale, 8 feet to an inch.



	Feet.
Quarry.	
Rather hard, thin bedded or platy whitish chalk	16
Hard, tough, massive grey chalk, with a layer of green-coated nodules at its base (Totternhoe Stone)	2½
Hard, creamy-white chalk in thick beds, passing down into greyer chalk	8
Boring.	
Hard, grey chalk, becoming gritty and shelly below, and having a layer of yellowish green-coated nodules at its base (Inoceramus Bed)	8
Very hard, compact white limestone	1½
Rather soft, greenish white marl, passing abruptly to	2
Pale, yellowish-buff marl, hard and compact at first, softer and browner below, passing gradually to ...	2½–3
Rather hard, clayey marl, mostly red but streaked or blotched with tawny-brown	2–2½
Reddish-brown sandstone ...	1
Total	44

For reasons already stated we refer the grey and coloured marls to the Gault, and regard the hard white limestone above them as the base of the Chalk, and as the equivalent of the so-called "sponge bed" at Hunstanton. The succeeding grey and shelly chalk is clearly identical with the "Inoceramus bed" of Hunstanton, and the overlying white chalk represents the higher part of the Chalk Marl of Stoke Ferry in the district to the south (Sheet 65); the total thickness of the zone of *Ammonites varians* at this locality being 19½ feet as compared with 75½ feet at Stoke, showing a rapid northerly attenuation.

* From *Quart. Journ. Geol. Soc.*, vol. xliii., p. 560.

The grey stone above corresponds in appearance and structure with the Totternhoe Stone of Burwell, and the layer of greenish nodules at its base resembles that which is locally called "the brassil" at Burwell. This layer may be traced all round the pit, though the nodules are more abundant and the layer consequently more evident in some places than in others. The stone above consists largely of comminuted shell-fragments, and the proportion of fine silt or sand is even less than in Cambridgeshire; glauconite grains are abundant. That its thickness should be so small is not surprising when we remember the general diminution in the thickness of the whole of the Lower Chalk when traced to the north.

The chalk above is whitish and contrasts with the grey bed below.

There is a large pit in the upper zone to the south-east of Ingoldisthorpe but neither base nor summit is exposed.

The quarry about half a mile south-east of Snettisham Church shows just the same succession; the Totternhoe Stone is a prominent feature, and fossils can be obtained from it in both pits (see p. 57), but there are fewer grains and the nodules at the base are not so clear as in the sections already mentioned. The Chalk below is more fully exposed, about 15 feet being visible, all hard, grey, and shelly, like the material of the Inoceramus bed at Hunstanton; the basal limestone must, in fact, be only a foot or so below the floor of this quarry.

One of the most complete sections of the Lower Chalk of Norfolk is exposed in the large quarry south-east of Heacham. The pit is worked in two levels, which give a continuous section of nearly 60 feet in depth, and the beds dip to the eastward at 3° to 5°.

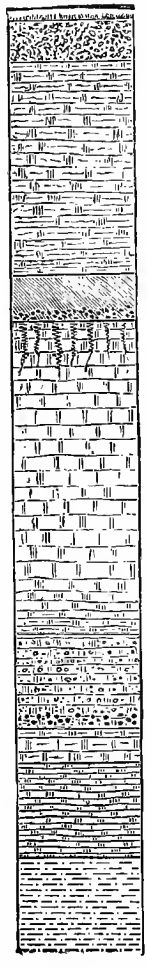
	Upper Level.	Feet.
	Soil and rough weathered chalk	3 or more.
Melbourn Rock	Hard, yellowish, nodular rock in massive beds; containing broken Inoceramus shells, and having a marly layer at the base	6
	Hard, whitish chalk in thin beds, forming two courses, separated by a thin band of buff-coloured marl	2
	Hard, whitish chalk, weathering into thin layers, the base obscured by talus	3 to 4
	Lower Level.	
Lower Chalk	Thin bedded platy chalk, with a marly bed near the top, becoming more massively bedded below ... ... at least	30
	Hard, grey, flaggy chalk, with a layer of green-coated nodules at the base: Totternhoe Stone	2
	Hard, bedded, cream-white chalk, becoming somewhat greyer toward the bottom ...	12 or more.
		About 59

The outcrop of the Red Chalk is seen at the entrance of the pit, and it can hardly be more than 6 or 7 feet below the base of the above section, so that the total thickness of the Lower Chalk here may be estimated at about 56 feet. The Totternhoe Stone is conspicuous by its decided grey colour, which contrasts with the white chalk below; the hardness and whiteness of all the beds except this band are, in fact, a noticeable feature. (For the fossils found here see p. 57.)

The next exposure of the Lower Chalk is in a quarry south-east of Hunstanton railway-station. Here the Red Chalk is seen near the entrance, overlain by about 30 feet of hard bedded chalk, including the Totternhoe Stone, which is 2½ feet thick with nodules at the base.

We now come to the well-known Hunstanton cliffs. The base of the Chalk, *i.e.*, the layer known as the "sponge-bed" (from the curious cylindrical bodies or concretions it contains), comes in at the top of the cliff about half a mile north of the railway-station; and the Totternhoe Stone takes the ground a little to the south of the lighthouse. The section (Fig. 4) was taken a little north of the lighthouse.

Figure 4. Section near the Lighthouse, Hunstanton Cliff. (JUKES-BROWNE and W. HILL.*)



Scale, 8 feet to an inch.

		Feet.
	Soil and chalk rubble	2
Grey Chalk	Thin-bedded whitish chalk, with some indefinite marly layers near the base	9
Totternhoe Stone	Compact dark grey gritty chalk, with nodules at the base	2
Chalk Marl, 18½ feet	Hard, creamy-white chalk, regularly bedded, becoming greyer below,	13
	and passing into	
	Hard grey and shelly chalk, full of broken fragments of Inocerami, and having a layer of greenish nodules at the base, with scattered nodules throughout	4
	Hard, white chalk, with branching cylindrical bodies	1½
Red Chalk	Red Chalk, pink at the top, dark red and sandy at the base	3½
Carstone	Ferruginous sandstone, seen for ...	4
		39

The white nodular limestone (or so-called "Sponge Bed") which forms the base of the Chalk Marl is separated by marked planes of division from the beds above and below. The basal

* From *Quart. Journ. Geol. Soc.*, vol. xliii., p. 562.

part of the bed is in places stained pink. It is full of irregular branching cylindrical structures, which bear a certain resemblance to the silicified stems of Siphonia, as preserved in the Upper Greensand of Wiltshire, and under the mistaken idea that they were really the remains of such sponges, the bed itself came to be known as the "Sponge Bed." The nature of these bodies has recently been studied by PROF. T. MCK. HUGHES, who found no trace whatever of any organic structure; they are filled with material exactly like that of the enclosing rock, and he concludes that they are a kind of concretionary structure* (see *ante*, p. 36).

The material of this white rock is a nearly pure limestone, containing about 94 per cent. of calcic carbonate. Under the microscope it is seen to consist largely of fine amorphous material, in which are enclosed calcareous spheres, Foraminifera, and small shell-fragments (see p. 49).

Fossils are common in this bed (see p. 57), the most abundant being *Avicula gryphæoides* and *Terebratula biplicata.*

The hard shelly rock above is known as the "Inoceramus Bed"; in reality there are two or three courses of grey shelly rock, the lowest being very rough and coarse in texture, containing large fragments of Inoceramus shell and many potato-like green-coated nodules. The succeeding beds are less coarse, and have a great resemblance to the Totternhoe Stone of Cambridge and Herts; they consist mainly of irregularly sorted fragments of shell, these forming about 60 per cent. of the mass; grains of glauconite are abundant, and the remainder is fine calcareous matter, chemical analysis showing 91 per cent. of calcium carbonate. The commonest fossil is a variety of *Holaster subglobosus*, a species which has not yet been found below the Totternhoe Stone in Cambridge, but occurs at this low horizon throughout the west of Norfolk.

There is a gradual passage upward into the hard white chalk which represents the mass of the Chalk Marl; in this shell-fragments are present but in less quantity, the proportion of fine amorphous matter being greater, and shells of Foraminifera, entire and broken, being more abundant; glauconite is rare or absent, and the rock is a nearly pure limestone.

The Totternhoe Stone is similar to that at Heacham and Dersingham. It forms a marked feature in the face of the cliff, and the fallen blocks of it can be distinguished from the Inoceramus bed by their darker colour, and by the finer grain and more even fracture of the rock. Its composition, as revealed by the microscope, has been described on p. 50.

Of the whitish chalk above there is little to be said; it weathers in a platy fashion, and corresponds entirely with that which overlies the Totternhoe Stone in the sections already described.

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* *Quart. Journ. Geol. Soc.*, vol. xl., p. 273.

Outlier.

The only outlier of Chalk in this sheet is that about half a mile N.N.E. of Roydon Church, and it is of much importance, inasmuch as it shows the basal beds of the Chalk Marl, and is the site of the boring mentioned on page 33, which pierced the Gault.

The lowest bed seen in the quarry is a very hard yellowish or creamy-white limestone containing *Terebratula biplicata* and *Avicula gryphæoides ;* this was found by digging to be over five feet thick, and to be yellower where it passed down into the soft marl below ; its upper part is piped with the grey material of the overlying bed. The beds above consist of hard grey shelly chalk, precisely like the material of the " Inoceramus Bed " at Hunstanton, and having a similar layer of green-coated nodules at their base. This shelly chalk has a thickness of about six feet, and was described by MR. WHITAKER in 1884* as possibly the representative of the Totternhoe Stone, he being struck by its similarity to that stone, just as the present writer was by the resemblance of the Hunstanton Inoceramus Bed to the same stone in 1880.† The boring recorded on page 33 made it clear, however, that the Roydon shelly rock was the equivalent of the Inoceramus Bed of Hunstanton. As in the latter, there is about 60 per cent. of coarse shell-fragments of various sizes and irregularly sorted ; glauconite grains are abundant, and the remainder is chiefly fine amorphous calcareous matter. The included green-coated nodules consist of compact limestone, like that of the underlying rock.

Fossils from the Lower Chalk.

The following list of fossils has been compiled from those published in the paper previously quoted (*Quart. Journ. Geol. Soc.*, vol. xliii.), from those given by DR. BARROIS in his " Recherches," and from specimens collected by MR. WHITAKER, which were named at Jermyn Street by MESSRS. SHARMAN and NEWTON. The localities from which the fossils were obtained are indicated by letters thus :—

D = Dersingham.
H = Hunstanton.
He = Heacham.
Hi = Hillington.
I = Ingoldisthorpe.
R = Ringstead, Barnet Ringstead Farm.
Sn = Snettisham, 1, south-east, 2, E.N.E.
W = West Newton, Prince of Wales' Water Tower.

The list from the upper beds in the Hunstanton cliff given by DR. BARROIS ("Recherches," p. 158), may include some specimens from the Totternhoe Stone, but we have entered them all in the column for the beds above that horizon.

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* *Proc. Norwich Geol. Soc.*, vol. i., p. iii., p. 238.
† See *Geol. Mag.*, dec. ii., vol. vii., p. 248.

FOSSILS FROM THE LOWER CHALK.

—	Chalk Marl.			Totternhoe Stone.	Grey Chalk.
	Basement Bed, Hunstanton.	Inoceramus Bed.	Upper Beds.		
Spongida.					
Leptophragma Murchisoni, *Goldf.*	×				
Plocoscyphia labrosa, *Mant.*	—	H —	D		
Strephinia convoluta, *Hinde*	×				
Ventriculites	—	— R	D		
Actinozoa.					
Onchotrochus serpentinus, *Dunc.*	—	H —	— — — —	— — — —	D H
Echinodermata.					
Cidaris Bowerbankii, *Forbes*	—	— —	— — — —	— — — —	— — Hi 1 ?
„ dissimilis, *Forbes*	?	H —	— H ? — —	— — — —	D — — — — W
„ uniformis, *Sorig.*	—	— —	— — — —	— — — —	— H
„ vesiculosa, *Goldf.*	×	H —	— — — —	— H	
„ sp. (Spines)	—	— —	— — — —	— — He Sn 2	— — Hi — R W
Discoidea cylindrica, *Lam.*	—	H —	— H — —	— — He —	— — Hi — R
Epiaster crassissimus, *d'Orb.*	—	H			
Holaster lævis, *De Luc* (var. carinatus, *Ag.*) ...	×				
„ rotundus, *J.-Browne*	—	H			
„ subglobosus, *Leske*	×	H —	D H He —	D H — —	D — Hi I R W
Pseudodiadema ornatum, *Goldf.*	—	H			
„ variolare, *Brongn.*	—	H			
Salenia Austeni, *Forbes*	—	— —	— — — —	— — — —	— H

FOSSILS FROM THE LOWER CHALK.

—	Chalk Marl.							Totternhoe Stone.				Grey Chalk.					
	Basement Bed, Hunstanton.	Inoceramus Bed.		Upper Beds.													
Annulosa.																	
Pollicipes unguis, *Sow.*	×	H	—	—	—	—	—	—	—	He							
Serpula annulata, *Reuss*	×	H	—	—	—	—	—	—	—	—	Sn 2						
,, subtorquata, *Münst.*	—	—	—	—	—	—	—	—	—	—	—	D	H				
,, sexangularis, *Münst.*	—	—	—	—	—	—	—	—	—	—	—	—	H				
,, (Vermicularia) umbonata, *Sow.*	×	H	—	—	—	—	—	—	—	—	—	—	H				
Brachiopoda.																	
Kingena lima, *Defr.*	×	H	—	—	H	—	—	—	H	—	—	D	H				
Magas Geinitzi, *Schloth.*	—	—	—	—	—	—	—	—	—	—	—	—	H				
Rhynchonella Cuvieri (?), *d'Orb.*	—	—	—	D	H	He?	Sn	—	—	—	—	—	H	—	—	R	W?
,, ,, coarse var.	—	—	—	—	—	—	—	D	—	He							
,, grasiana, *d'Orb.*	—	H	—	D	H	—	—	—	—	—	—	D?					
,, lineolata, *Phil.*	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	R	
,, Mantelliana, *Sow.*	—	H	—	D?	H	—	Sn	—	H	He	Sn 1						
,, Martini, *Mant.*	—	—	—	—	—	—	Sn	D	—	—	Sn 2	—	H	Hi			
,, ,, var. like lineolata	×																
Terebratula biplicata, *Sow.*	×	H	R	—	H	He	—	D	H	He	Sn 1, 2	—	—	Hi			
,, ,, var. Dutempleana, *Sow.* ...	×																
,, ,, ,, obesa	—	—	—	—	—	—	—	—	—	He							
,, ,, ,, obtusa	×	H															
,, semiglobosa, *Sow.*	×	H	R	D	H	He	Sn	D	H	He	Sn 1, 2	D	H	Hi	I	R	W

—	Chalk Marl.												Totternhoe Stone.				Grey Chalk.					
	Basement Bed, Hunstanton.	Inoceramus Bed.		Upper Beds.																		
Brachiopoda—(continued).																						
Terebratula squamosa (?), *Mant.*	—	—	—	—	—	—	—	—					—	—	—	—	—	H				
„ subundata, *Sow.*	×	—	—	—	—	—	—	D	?	H	—	Sn	1									
„ sulcifera, *Morr.*	×	H	—																			
Terebratulina triangularis, *Eth.*	—	H	—	D	H	—	Sn	—		H	—	—					D	H				
„ gracilis, *Schl.* (var. nodulosa, *Ether.*)	×	—	—	—	—	—	—	D		H	—	—					D					
„ striata, *Wahl.*	×	—	—	—	—	—	Sn															
Lamellibranchiata.																						
Avicula filata, *Ether.*	—	—	—	—	—	—	—	—		—	—	Sn	1									
„ gryphæoides, *Sow.*	×	H																				
„ Roxelana (?), *d'Orb.*...	—	—	—	—	—	—	—	—		—	—	—					—	H				
„ new sp.	—	—	—	—	—	—	—	D														
Exogyra haliotoidea, *Lam.*	—	—	—	—	—	—	—	D		—	—	Sn	2									
Inoceramus latus, *d'Orb, non Mant.*...	×	H	R	—	H	—	Sn	D		—	He	Sn	1									
„ mytiloides, *Mant.*	—	—	—	—	—	—	—	—		—	—	—					—	—	—	I	?	R W
„ striatus, *Mant.*	—	H	—	—	H																	
Lima cenomanensis, *d'Orb.*	—	—	—	—	H	—	—	—		—	—	—					D	H				
„ echinata, *Ether.*	—	H	—	—	—	—	Sn															
„ elongata, *Sow.*	—	—	—	—	—	—	—	—		—	—	—					—	H				
„ globosa, *Sow.*	—	H	R	—	H	—	—	D		—	He											
„ ovata (?), *Nilss.*	—	H																				

	Chalk Marl.																					
	Basement Bed, Hunstanton.	Inoceramus Bed.		Upper Beds.				Totternhoe Stone.				Grey Chalk.									
Lamellibranchiata—(continued).																						
Ostrea frons, *Park.*	—	H										—	H								
„ Lesueuri, *d'Orb.*	—	—	—	—	—	—	—	—	—	—	—											
„ vesicularis, *Lam.*	×	H	R	—	—	—	—	—	H	He	Sn 2	D	—	Hi	I	R	W					
„ pectinata, *Lam.*	—	H																				
„ sp. (in the nodules)	—	—	—	—	—	—	—	D														
Pecten Beaveri, *Sow.*	—	H	—	—	—	—	—	D	H	—	Sn 1											
„ elongatus (?), *Lam.*	—	H																				
„ orbicularis, *Sow.*	×	H	—	—	—	—	—	D	H	He	Sn 1	—	—	Hi								
Plicatula inflata, *Sow.*	×	H	R	D	H	He	Sn	—	—	He	—	D	H									
Spondylus striatus, *Sow.*	×	H	R?																			
„ lineatus, *Goldf.*	—	H																				
Gasteropoda.																						
Pleurotomaria	—	H	—	—	H	—	—	—	H													
Trochus cirrus (?), *Woodw.*	—	—	—	—	—	—	—	D	—	He												
Cephalopoda.																						
Ammonites (Desmoceras) Austeni, *Sharpe* ...	—	H																				
„ (Acanthoceras) cenomanensis, *d'Arch.*	—	—	—	—	—	—	—	—	—	—	—	—	—	Hi								
„ (Schloenbachia) Coupei, *Brongn.* ...	—	—	—	—	—	—	—	—	—	He												

—	Chalk Marl.			Totternhoe Stone.				Grey Chalk.						
	Basement Bed, Hunstanton.	Inoceramus Bed.	Upper Beds.											
Cephalopoda—(continued).														
Ammonites (Haploceras) lewesiensis (?), *Mant.* ...	—	— —	— — — —	— — —	—			— —	Hi	—	—	W		
„ (Desmoceras) planulatus (?), *Sow.* ...	—	— —	— — — —	— — —	—			D						
„ (Acanthoceras) rotomagensis, *Brongn.*	—	H —	— — —	— — —	Sn 2									
„ (Schloenbachia) varians, *Sow.*	—	— —	— H?											
„ sp.	×													
Actinocamax plenus, *Blainv.*	—	— —	— — — —	— — —	—			—	H					
Belemnites minimus, *List.*	×	— —	— — — —	— — —	Sn 1									
„ ultimus, *Sharpe*	×	H												
Turrilites costatus (?), *Lam.*	—	— —	— — — —	D — —	Sn 1									
„ tuberculatus, *Bosc.*	—	— —	— — — —	D										
„ sp.	—	— —	D											
Nautilus sp.	—	H												
Pisces.														
Beryx	—	— —	— — — —	D —	He	—		— —	—	I				
Cimolichthys lewesiensis, *Leidy*	—	— —	— — — —	— — —	Sn 1									
Edaphodon	—	— —	— — — —	D										
Enchodus	—	— —	— — — —	— —	He	—		— —	—	I				
Lamna appendiculata, *Ag.*	×													
„ sp.	—	— —	— — — —	D —	He	Sn 1								
Ptychodus decurrens, *Ag.*	—	— —	— — — —	— — —	—			— —	Hi	—	R			

Remarks.

The fossils from the basement-bed at Hunstanton were collected by MR. H. G. FORDHAM, who devoted himself to collecting from this bed when visiting Hunstanton. The species were identified by himself, except the sponges which were named by DR. G. J. HINDE.

The assemblage is not quite the same as that found in the Chalk Marl of Cambridgeshire and the south of England; the species are in the main the same, but their relative abundance is very different. Thus *Ammonites varians*, which is so common and characteristic a fossil of the Chalk Marl throughout the midland and southern counties, becomes very rare in Norfolk, so rare that it is not certain whether it has ever been found in the neighbourhood of Hunstanton. The same may be said of *Ammonites Mantelli*, which is very common in the south of England, rare in Cambridgeshire, and still rarer in Norfolk. *Rhynchonella Martini*, again, is so common to the southward that it was thought the zone might bear its name, but it becomes so rare in Norfolk that the typical form has only been found at Snettisham, that in the basement-bed at Hunstanton being a fine-ribbed variety which has much affinity with *Rhynchonella lineolata*.

But while some species elsewhere common become rare in Norfolk there are others, seldom found in this zone elsewhere, which are very abundant in Norfolk. Of these the most important is *Holaster subglobosus;* so rare is this species in the Chalk Marl of the counties between Suffolk and Oxfordshire that no specimen has passed through my hands. In the shelly "Inoceramus Bed" near the base of the Norfolk Chalk Marl it is, however, very common, and it also occurs occasionally in the beds between that and the Totternhoe Stone. There can be little doubt that the conditions of depth and current-action which were specially favourable to this urchin, existed at an earlier period in Norfolk than in the middle and south-east of England.

A. J. J.-B.

CHAPTER 5. MIDDLE AND UPPER CHALK.

MIDDLE CHALK.

General Remarks.

When this district was mapped by the officers of the Survey, the staff was being pressed to finish the one-inch map of England, and little endeavour was then made to work out the zonal divisions of the Chalk, which would have delayed the completion of the mapping. As already stated (p. 46), Mr. W. Hill repeatedly visited West Norfolk in 1886 and 1887 for the purpose of studying the Gault and Lower Chalk, and aided by Mr. Whitaker he succeeded in fixing the upper limit of the Lower Chalk by identifying the Melbourn Rock which forms the basement-bed of the Middle Chalk. They traced the course of its outcrop, and the line thus drawn was engraved on the Geological Survey map.

It should be mentioned that the existence of this rocky band at Shernborne had been noticed by Dr. C. Barrois so far back as 1875, and had been correctly referred by him to the base of his zone of *Inoceramus labiatus*. He also described the chalk of the *Terebratulina gracilis* zone as occurring near Sedgeford, and that of the *Holaster planus* zone as cropping out by Docking, Bircham Newton, and Great Bircham. These three zones make up the Middle Chalk or Turonian of Dr. Barrois, and to him therefore is due the credit of localising these zones in West Norfolk.

Still more recently (in 1897) Mr. Hill revisited West Norfolk for the purpose of studying the highest beds of the Middle Chalk and the lower part of the Upper Chalk; in the hope of bringing this part of the Norfolk Chalk into correlation with that of the more southern counties. He found great difficulty in doing this because of the lithological changes which take place in the character of the Middle Chalk as it is traced through the country, and also because the exposures are few and seldom of any great depth, and because fossils are scarce.

Dr. Barrois thought that the zone of *Holaster planus* in Norfolk was characterised by the presence of grey flints, and consequently "that all the quarries in which the grey flints are found may be referred to the zone of *Hol. planus*."* Mr. Hill, however, found that grey flints occurred in the zone of *Terebratulina gracilis*, and that those in the zone of *Holaster planus* are not exactly grey, being much darker, and more correctly described as greyish-black. Moreover, he saw reason to think that the higher beds in which these grey-black flints occurred did not belong to the *Hol. planus* zone but to the zone of *Micraster cortestudinarium*. In the absence of fossils, however,

* "Recherches sur le Terr. Crét. sup.," p. 162.

this must remain a doubtful point, and MR. HILL did not observe any bed resembling the Chalk Rock within the area of Sheet 69; so that the exact line of division between Middle and Upper Chalk still remains doubtful.

ZONE OF RHYNCHONELLA CUVIERI.

In this part of Norfolk the chalk of this zone is hard, rather rough, and veined by irregular seams of bluish-grey marl, so that when weathered it splits up into thin platy fragments. The lower part for seven or eight feet is very hard, rough, and nodular, with many broken fragments of Inoceramus shell, and this is clearly the equivalent of the Melbourn Rock. The higher beds are less shelly and less nodular, and these pass up into similar chalk in which layers of grey flint-nodules occur.

We are inclined, however, to limit the zone of *Rhynchonella Cuvieri* to the portion which is without flints or, at any rate, without regular layers of flints, referring the more flinty chalk to the zone of *Ter. gracilis*. Of this hard flintless chalk the thickness cannot be great, possibly not more than 30 feet.

Details.

The outcrop of the rocky chalk which forms the base of this zone enters the district to the east of Roydon and passes through a pit on the southern side of Congham Common and close to the top of the large quarry south of Hillington, if, indeed, it is not shown in that quarry as suggested on p. 50.

In the railway-cutting to the east of Hillington Station there is hard yellowish chalk, breaking with a rough fracture and containing numerous fragments of *Inoceramus*-shell. These beds are probably just above the Melbourn Rock. Proceeding eastward up the cutting the chalk gradually becomes whiter, less shelly, and not so hard or rough, though firm and thick-bedded.

No exposures were found between Flitcham and Shernborne, but less than a quarter of a mile north of Shernborne Church hard yellowish nodular chalk was seen in a small exposure by the roadside, close by an old quarry the sides of which are now overgrown and its floor cultivated. This is doubtless the quarry mentioned by DR. BARROIS,* in which he recognised "the hard nodular bed which throughout England occurs at the base of the zone of *Inoceramus labiatus*," and which is now called the Melbourn Rock. DR. BARROIS obtained here *Ammonites nodosoides*, *Rhynchonella Cuvieri*, and other fossils (see list on p. 69).

What we take to be the highest part of this zone is exposed in a quarry about half a mile south-east of Sedgeford Church. This is described by MR. WHITAKER as hard, massive, bedded, and jointed chalk, with a nodular structure in parts. It is

* "Recherches sur le Terr. Crét. sup.," p. 160.

doubtless the quarry mentioned by DR. BARROIS (Recherches, p. 161) as showing "white marly chalk, without flints, and weathering into small platy pieces." He records the following fossils *Inoceramus Brongniarti*, *Inoc. sp.*, *Terebratula semiglobosa*, *Holaster coravium* [? species], and *Echinoconus subrotundus*, and he refers it to the zone of *Terebratulina gracilis*. It certainly cannot be far from that zone, but as flints are absent we group it in the lower zone.

The cutting on the railway, three quarters of a mile east of Sedgeford Station, shows similar chalk, and there is also a small quarry in a field adjoining the cutting. From these exposures MR. HILL and MR. RHODES obtained the fossils listed on p. 69.

Returning to the base of the zone, this trends north-westward from Shernborne and passes above Snettisham toward Heacham, and the equivalent of the Melbourn Rock is well exposed at the top of the large quarry south-east of Heacham.

About six feet of very hard yellowish nodular rock is here seen (see p. 53); it lies in thick beds, but where these are weathered they split up into thin platy pieces along veins of greenish marly material, the lumps having rough and uneven surfaces. The base of this nodular chalk is clearly marked, but it rests directly on hard white chalk without the intervention of any marly bed. There is, however, a thin layer of buff-coloured marl in the white chalk about a foot below what we take as the base of the Melbourn Rock.

The upper bed of the Melbourn Rock and part of the overlying chalk are exposed in the railway-cutting north-west of Sedgeford, and have yielded some fossils.

Another good exposure occurs in the quarry north-east of Barret Ringstead Farm; the following account of the section being compiled from the notes of MESSRS. WHITAKER and HILL :—

		Feet.
Rubble of hard broken chalk		about 6
Middle Chalk.	Hard, rough, creamy-white chalk	„ 3
	Very hard, rough, yellowish, nodular rock, with much broken Inoceramus-shell, in two massive beds, each about 3½ feet thick (Melbourn Rock)	„ 7
Lower Chalk.	Dull, white, thin-bedded chalk, divided by thin grey marly seams and weathering into platy fragments	„ 12 or 13
	Greyish-white chalk, in thicker beds, hard and massive, with marly seams...	„ 4
		32

In the rough shelly rock *Rhynchonella Cuvieri* and *Inoceramus mytiloides* are common. The chalk is much jointed, and slices seem to have slipped along the joints towards the valley, so that at the end of the pit it is seen to be much shattered and broken.

ZONE OF TEREBRATULINA GRACILIS.

In this part of Norfolk the chalk of this zone differs considerably from that of the same age in more southern counties. Instead of the soft, smooth, white, massively-bedded chalk, with occasional layers of soft grey marl, which is its usual character in the South of England, there is here a hard white veiny chalk,

differing little from the chalk of the *Rhynchonella Cuvieri* zone, except in being whiter and in containing many layers of flints, as well as some very large Paramoudra-like flints.

Moreover, the fossil which is so characteristic of the zone in southern counties (*Terebratulina gracilis*) is very rare or absent in Norfolk, for hitherto no specimen has been found. Some fossils, however, occur, and among them *Inoceramus Cuvieri*, *Inoceramus Brongniarti* (?) and *Echinoconus subrotundus*, which are common in this zone elsewhere.

Details.

This Chalk enters the district between Congham Common and Great Massingham.

What appears to be the base of the zone is exposed in a small chalk-pit, in a field less than a mile E.N.E. of Hillington Church, between the wood and the railway. MR. WHITAKER visited this pit, and describes it as showing "hard white chalk, with a layer of flint-nodules in the upper part."

The eastern end of the railway-cutting north of this pit is probably in the same chalk, and from this MR. RHODES obtained (at about 1¼ mile east of the station) *Inoceramus Brongniarti* (?), *Inoc. Cuvieri*, and a portion of a *Cidaris*.

The higher part of the zone is (or was) exposed in an old pit 2¼ miles east of Hillington Church, near the hill-top, and just north of the gravel-spur. Of the chalk here seen MR. WHITAKER notes that "it is partly hard, but none of it quite so hard as that of the lower beds, and it contains layers of flints, one near the bottom being apparently continuous and rather thick. There is a small fault or slip of about a foot downthrow on the west."

MR. WHITAKER also noted a quarry "about a mile and a quarter E.N.E. of Flitcham, which showed rather hard chalk with large flints, some forming nearly continuous layers. At the top is a very hard layer overlain by a layer of soft marl."

A chalk-pit at Fring, a little south-east of the church, gives a good section in part of this zone. MR. WHITAKER saw it in 1883 and notes that about 30 feet of chalk was exposed, "about six feet or more down are two layers of flints about 1½ feet apart, partly tabular but not continuous throughout. Below these, for about 15 to 20 feet, there seem to be no flints. Then comes a layer of flint-nodules and below it about five feet more of chalk." MR. WHITAKER did not see any fossils, but MR. HILL, visiting the pit in 1897, succeeded in finding *Rhynchonella Cuvieri* and *Echinoconus subrotundus*.

The quarry south-east of Sedgeford referred by DR. BARROIS to this zone is regarded by MR. HILL and ourselves as belonging to the zone of *Rhynchonella Cuvieri* (see p. 65).

The lower beds of the *Ter. gracilis* zone are exposed in a fairly large quarry a quarter of a mile south of Ringstead St. Andrew's. This is about 25 feet deep, and shows beds of hard veiny chalk with a few grey flints, none of large size. MR. RHODES obtained a few fossils from this pit (see list, p. 69).

The quarry three quarters of a mile south of Holme is probably in the same zone, the chalk being hard and white, and some of the same fossils were found in it by MR. RHODES.

Regarding the quarry half a mile south of Thornham MR. HILL writes, in 1897: "This must be quite at the top of the *Ter. gracilis* zone. There are two faces, and about 30 feet of chalk are exposed. It is very veiny, the veins being strongly marked in rather dark grey marl, and it weathers along these veins into platy pieces. There are, however, some layers without veins which weather as a whole without splitting, and are from a foot to 18 inches thick. There are several layers of large grey flints, and some large Para-

moudra flints were exposed. *Terebratula semiglobosa* and fragments of a large *Inoceramus* were the only fossils seen."

Zone of Holaster planus.

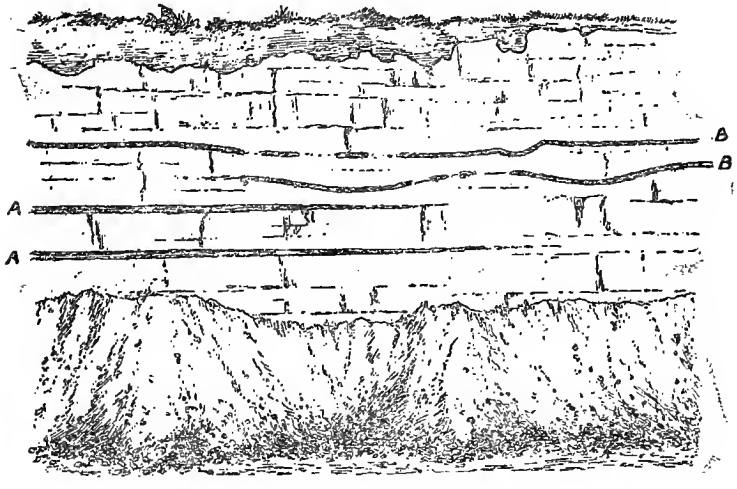
Lithologically, so far as this part of Norfolk is concerned, the zone of *Holaster planus* is a continuation of that of *Terebratulina gracilis*. The chalk is firm and rather hard, and contains grey flints, which occur in three forms, *i.e.*, as small nodules either scattered or in layers, in flattened lenticular masses which are sometimes nearly continuous floors, and as large irregular "Paramoudras."

The extent and thickness of this zone is uncertain, because at present the characteristic fossil (*Holaster planus*) has only been found in two or three pits; but the following places are well within the limits of its outcrop: Massingham, Harpley, Houghton, the Birchams, Docking, and Titchwell.

Details.

The most southerly pit referable to this zone is one noted by Mr. Whitaker over half a mile west of Little Massingham Church; in this he found rather hard chalk with a few scattered nodular flints and a thin continuous layer of flint.

Figure 5.—Chalk-pit about one mile west of Harpley Church.
(H. B. Woodward.)



B. Layers of tabular flint.
A. Seams of laminated clayey earth.

The following notes on the area round Harpley, Houghton, and Bagthorpe are by Mr. H. B. Woodward:—

About a mile west of Harpley Church there was a large pit showing 20 feet of hard white Chalk dipping at about 2° E. 35° N. (see Fig. 5).

The surface of the Chalk was disturbed and piped, and Boulder Clay was present on the higher ground not far away. About the middle of the face of Chalk there were some interrupted layers of tabular flint, slightly undulating and not parallel, two to four inches in thickness ; and these contain in places *in the flint* lenticular seams of chalk. The flint occurs along the planes of bedding. Lower down there were two thin layers of laminated clayey earth. In the absence of fossils it is impossible to say whether this chalk belongs to the zone of *H. planus* or to that of *Ter. gracilis*.

A pit by the border of the park north-east of Houghton Church showed blocky white Chalk (about 20 feet) with three isolated layers of tabular flint. Here and there the flint and Chalk were stained bright red on the surface with iron-oxide. Above the Chalk was a weathered layer of chalky Boulder Clay, five to eight feet in thickness.

West of Bagthorpe a pit showed the Chalk with impersistent layers of tabular flint, and an irregular top of Boulder Clay and flint gravel.

Between Bagthorpe and Bircham Tofts the Chalk is covered by a thin and irregular deposit of Boulder Clay ; and it is a question whether or not more bare Chalk might have been shown on the map. H. B. W.

In 1897 MR. W. HILL determined the existence of the zone of *Holaster planus*, near Great Bircham, in a quarry three quarters of a mile N.N.W. of the church which showed the following section :—

	Ft.	In.
Soil and broken chalk	3	0
Layer of large separate flat lenticular flints grey-black inside	0	6
Chalk, much broken, with *Holaster planus* ...	6	6
Layer of large grey-black flints	0	6
Broken Chalk with a few scattered small flints (*Rhynchonella* sp.)	3	0
Layer of large massive flints	0	9
Chalk, seen for	1	6
	15	9

DR. BARROIS had previously indicated this zone in a neighbouring quarry ; he writes : "To the west of Bircham Newton a large quarry is opened on the same horizon, in a hard white chalk with nodules of grey flint, and grey tabular layers from 2 to 2½ inches thick, and less than three feet apart. Between these layers there are large isolated flints similar to those which are so frequent in the Norwich Chalk, and which are known by the name of *Paramoudras*. There are in this quarry layers of nodular chalk. I collected *Ammonites prosperianus*, d'Orb., *Echinocorys gibbus*, Lam., *Holaster planus*, Mant."

He then mentions the Glacial clay and reconstructed Chalk which cover the surface of the chalk between Bircham and the neighbourhood of Docking, where the *H. planus* zone is again seen and where he collected *Belemnites* sp., *Rhynchonella plicatilis*, Sby., *Ostrea vesicularis*, Lam., *Holaster planus*, Mant., and *Echinocorys gibbus*, Lam. "The presence of a Belemnite at this horizon is interesting ; it is a fragment, the precise determination of which is unfortunately not possible : it is comparable with *Bel. Strehlensis*, Fritsch."

In the pit a quarter of a mile north-west of the church at Docking, MR. C. REID noted chalk with a dip of 60° to the E.S.E., but this may be a mass included in the Glacial Drift (see p. 78).

The Chalk seen in a quarry a quarter of a mile south of Titchwell Church may be regarded as belonging to this zone, although no fossils have been found in it to confirm this determination. MR. HILL, who visited it in 1897, communicates the following note :—"The quarry-face shows from 35 to 40 feet of rather firm and massive white chalk with layers of grey-black flints and some scattered nodules. About 10 feet from the top is a conspicuous layer of flattened flints about four inches thick. This layer seems to form a nearly continuous floor, but its surface is uneven and knobbly. A similar layer, but less thick, occurs about 18 inches beneath it."

In the following list the localities are indicated thus :

Sh = Shernborne.	F = Fring.	BH = Great Bircham.
Se = Sedgeford.	R = Ringstead.	B = Bircham Newton.
H = Heacham.	Th = Thornham.	D = Docking.

LIST OF FOSSILS FROM THE MIDDLE CHALK.

——	Zone of Rhynchonella Cuvieri.			Zone of Ter. gracilis.			Zone of Holaster planus.		
Echinodermata.									
Cidaris sp. (spines)	—	—	—	—	R	—	BH		
Cardiaster sp. (? pygmæus) ...	—	—	—	—	R				
Cyphosoma sp.	—	—	—	—	—	—	BH		
Discoidea minima, *Ag.*	Sh	—	—	—	R				
Echinoconus subrotundus, *Brong.*	—	Se	H	F	R				
Echinocorys vulgaris, *Breyn.* ...	—	—	—	—	—	—	—	B	D
Holaster planus, *Mant.*	—	—	—	—	R?	—	BH	B	D
Micraster sp.	—	—	—	—	—	—	BH		
Brachiopoda.									
Rhynchonella Cuvieri, *d'Orb.* ...	Sh	Se	H	F	R				
„ Martini (?), *Mant.*...									
„ reedensis, *Eth.* ...	—	—	—	—	—	—	BH		
„ plicatilis, *Sow.*(large)	—	—	—	—	—	—	BH	—	D
Terebratula carnea, *Sow.* ...	—	—	—	—	—	—	BH		
„ semiglobosa, *Sow.*...	—	Se	H	—	R	Th	BH		
Terebratulina striata (?), *Wahl.*...	—		H						
Lamellibranchiata.									
Inoceramus mytiloides, *Mant.* ...	Sh	Se	—	—	R				
„ Brongniarti, *Sow.* ...	—	—	H	—	—	Th			
„ Cuvieri, *d'Orb.* ...	—	—	H						
„ sp.	—	—	—	—	—	—	BH		
Ostrea vesicularis, *Lam.*... ...	Sh	—	H	—	—	—	—	—	D
Cephalopoda.									
Ammonites (Acanthoceras) nodosoides, *Schoth.* ...	Sh								
„ (Pachydiscus) peramplus, *Mant.* ...	—	Se?	—	—	—	—	—	B	
„ (Acanthoceras) rusticus (?), *Sow.* ...	—	Se							
„ large smooth sp. ...	—	—	H						
Belemnites sp.	—	—	—	—	—	—	—	B	

UPPER CHALK.

As already mentioned it is very difficult if not impossible to say where the Upper Chalk begins in West Norfolk, and particularly in our district. DR. BARROIS thought that all the chalk with grey flints might be referred to the Middle Chalk, but at the same time he admits that he was unable to recognise the zone of *Micraster cortestudinarium* in a positive manner. MR. W. HILL has recently visited all the quarries and exposures that he could find in the eastern part of this area, and cannot agree with DR. BARROIS in referring all the chalk with grey and blackish-grey flints to the zone of *Holaster planus.* He thinks

the higher part of this chalk may belong to the zone of *M. cortestudinarium*, and he even found black-grey flints in some of the quarries referred by DR. BARROIS to the zone of *M. coranguinum*.

With the exception of *Echinocorys* (*Ananchytes*) *vulgaris*, fossils are so rare in these pits that it is very difficult to determine the question. In the first place, no specimen of *Micraster cortestudinarium* has yet been found; but if we eliminate those places where *Holaster planus* has been found and those where *Micraster coranguinum* occurs, there is left a tract of country in which a few scattered exposures are to be seen, and these may provisionally, for the sake of convenience, be referred to the zone of *Micraster cortestudinarium*.

? ZONE OF MICRASTER CORTESTUDINARIUM.

This band of chalk which we provisionally correlate with that of *Micraster cortestudinarium* underlies all the south-eastern corner of the area by Rudham, Tatterset, Bagthorpe, Barmer, and Syderstone. With it may also be classed that exposed at South Creake, and that in the valley between Stanhoe and Burnham Westgate.

Details.

The first noticeable quarry is that marked on the Geological Survey map about a mile north-east of Rudham Station. MR. WOODWARD contributes the following note:—This pit showed Chalk with a thin covering of brown soil and chalky Boulder Clay, altogether about 20 feet in thickness being exposed. Impersistent lines of tabular flint and two irregular layers of nodular flint occurred. Besides these there were at least three veins of what might be called "cross courses," or vertical and oblique veins of flint. The Chalk was evidently disturbed, and it appeared as if the tabular layer of flint had been shifted so as partly to overlap itself.

MR. HILL visited this pit in 1897 and reports that it is about 30 feet deep in chalk with greyish-black flints, some rather large. He found a fragment of a *Belemnite* and a small *Rhynchonella*.

South-east of Rudham Church MR. WOODWARD found a pit which showed tolerably hard chalk with a few lines of black and grey flint and balls of flint.

Another quarry, about half a mile north-east of Houghton Church, may also be referred to this zone. MR. HILL saw it in 1897 and writes,—It is in rather softer white chalk than is usual and the flints are blacker and smaller in size. About 25 feet of chalk is shown, but the only fossils seen were a fragment of a *Cidaris* spine and a crushed *Echinocorys vulgaris*.

MR. G. BARROW contributes the following note:—Another patch of Chalk commences at Barmer House and stretches in a comparatively narrow strip along the east side of the road towards Syderstone. North of Barmer are two shallow clay-pits having chalk at the base containing rows of large flat flints and bands of very hard chalk.

Chalk is also exposed in a pit about a quarter of a mile south-east of Syderstone Church.

The following is a translation of a note by DR. BARROIS:—"I have not identified the zone of *Micraster cortestudinarium* in a positive manner, but I refer to it a chalk with numerous *black* flints, visible in the cutting to the east of Stanhoe Station. I have not, however, recognised the characteristic fossils."*

* "Recherches sur le Terr. Crét. sup.," p. 162.

Of the Chalk in this cutting MR. BARROW remarks that it is hard and almost flaggy; when treading upon a heap of fresh fragments of this rock the pieces ground together emit a slight clinking sound. This outcrop would seem to continue along the bottom and lower flanks of the little valley through which the railway runs, though here and there small patches of clay are seen.

ZONE OF MICRASTER CORANGUINUM.

It is somewhat doubtful how much of this zone comes within our area. The chalk of Burnham Overy certainly belongs to it, and DR. BARROIS regarded that of North and South Creake in the same valley to the southward as also a part of it. MR. W HILL visited these localities in 1897, and found that the flints in the South Creake Chalk are dark grey, while those at Burnham Overy are darker grey-black, and some black; the only fossil he could find at South Creake was the ubiquitous *Echinocorys vulgaris*. He is consequently doubtful whether it is really in the *M. coranguinum* zone. On the other hand, DR. BARROIS records from this pit not only *Micraster coranguinum* but also *Echinoconus conicus*.

Taking all the facts into consideration we are inclined to place this chalk of South Creake in the zone of *M. coranguinum*, though it is probably quite at its base, and that of Burnham Overy is doubtless a little higher up.

Details.

DR. BARROIS says*: "This zone is quarried to the south of South Creake. The chalk contains layers of black banded flints, from one to two metres apart. Ferruginous infiltrations have coloured this chalk in several places, penetrating along the flint layers. At the base of one of the quarries are fragments of Inocerami, such as often occur at this horizon; in the upper part there are thin layers of clayey marl." He mentions the following fossils :—*Micraster coranguinum, Echinocorys gibbus, Echinoconus conicus, Ostrea hippopodium, Plicatula sigillina, and Inoceramus sp.*

The following is a note on one of these pits by MR. J. RHODES:—South-west of the church at South Creake a pit showed thick beds of hard Chalk, with bands of nodular flint. Among the fossils were *Terebratula*, *Rhynchonella*, fragments of *Inoceramus*, *Ostrea*, spines of *Cidaris*, fragments of *Ananchytes*, and *Ventriculites*. The fossils were most abundant 5 feet above the bottom of the pit."† MR. HILL notes that there is now (1897) from 20 to 25 feet of chalk exposed in this quarry.

MR. H. B. WOODWARD remarks that "chalk is well exposed in pits north of Burnham Overy Church, and to the east of Burnham Thorpe; it may be seen also in the cutting east of the railway-station, where the beds are hard and flaggy. The pit close to the church at Burnham Thorpe showed well-bedded chalk in layers of irregular thickness and durability. Even layers and some irregular masses of dark bluish-grey flint occurred, mostly in partings between the beds."

DR. BARROIS refers the Chalk of Burnham Overy to the zone of *Micraster coranguinum*, and says, "it is a rather hard white chalk, in beds from 3 to 5 feet thick, separated by (layers of) rather large black flints. Fossils are not common." He mentions the following *Inocerami* (with thick shell), *Spondylus latus, Echinocorys gibbus, Amorphospongia globosa.*

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* Translated from "Recherches sur le Terrain Crétacé supérieur," p. 162.

† From the note-book of MR. J. RHODES. Other fossils from South Creake (pit in the area of 68 S.W.) are noted by MR. WOODWARD in the explanation of the adjoining map, "Geology of Fakenham, &c.," p. 7.

MR. W. HILL visited the quarry at Burnham Overy, north of St. Clement's Church, in 1897, and took the following section :—

	Feet.	Inches.
Soil and rubble	2	0
Firm (but not very hard) white chalk with flints, both scattered and arranged in lines about 18 inches apart ... ... about	15	0
A thin parting of marl	0	1
Rather rough and harder white chalk. *Echinocorys vulgaris*	1	0
Thin parting of marl	0	1
Hard white chalk, containing cream-coloured lumps, some thin flints at the base at intervals. *Micraster sp.*	1	3
Parting of marl	0	1
White chalk, containing hard crystalline lumps, passing down to smoother, softer, but firm, white chalk	3	0
Firm, white chalk with flints, seen for ...	8	0
	30	6

A. J. J.-B.

CHAPTER 6. GLACIAL DRIFT.

General Remarks.

In the area under description, the most prevalent Glacial deposit is a light-coloured marly or chalky Boulder Clay, but associated with this are loams or brick-earths, with sands and gravels of a varying degree of coarseness. On the northern and western borders of Norfolk, and also north of Boston, there appears to be a different kind of Boulder Clay which is brown or reddish in colour, and contains very little Chalk *débris*, but many stones from distant sources. With this clay also are associated a varied series of loams, sands, and gravels.

It is possible that the one set of Glacial Drifts is older than the other set, but no clear evidence of such difference in age was obtained during the survey of the area, and consequently no attempt was made to separate them on the map. The colours on the map distinguish, as far as possible, the stony clays (or boulder clays), and the clean loamy clays or brick-earths from the sands and gravels. This is a lithological division, but as the boulder clays often pass into clays (with few stones) which are used for brick-earth, and as the one is sometimes interbedded with the other, as well as with sand or gravel, the distinction cannot be made consistently accurate for all localities.

The sands and gravels do not occur on one horizon, but occur sometimes below Boulder Clay, sometimes as lenticular beds and masses in such clay, but more often, in the area under consideration, they overlie the mass of Boulder Clay. There are also places where the gravels seem to be banked up against the clay, or where clay has cut out some part of a previous deposit of gravel and sand, and there are cases where it is impossible to say which kind of material was first accumulated.

As the grey and chalky Boulder Clay, with its associated beds, covers a large portion of the Chalk area, and also underlies a great part of the Fenland tract, we shall describe this group first without, however, making a definite assertion that it is the older group. The Boulder Clay will be described in the first place, and the sands and gravels subsequently in a separate chapter, irrespective of their superposition.

Finally, as the Brown Boulder Clays and loams seem to occupy distinct and separate surface areas from the chalky clays, they and the associated sands and gravels will be described in another chapter; it should be remembered that the Brown Clay is probably superimposed on the Grey Boulder Clay at and north of Boston, and possibly elsewhere.

The Glacial Drift on the chalk area varies greatly in thickness, from a mere remnant of a few feet to a depth of 40 or 50 feet. Many wells have been sunk through it to the chalk, but only two are said to have traversed more than 50 feet, and of this one (at Docking), conflicting accounts are given; in the other (at Massingham), the depth of Boulder Clay is said to be 100 feet.

Under the Fenland the Glacial Drift varies similarly in depth. It consists, so far as known, entirely of Boulder Clay, and this has a thickness of 30 feet at Lynn (under 20 feet of Fen Beds), but is said to be over 90 feet at Long Sutton (under 57 feet of Fen Beds), and is probably 166 feet thick at Boston (under 24 feet of Fen Beds.)

Chalky Boulder Clay.

The Boulder Clay on the higher ground in the eastern part of the area comprised in Sheet 69 forms part of the great spread of Glacial Drift which covers so much of Norfolk. The clay is generally of a light colour, pale grey, buff or whitish, and contains much chalky matter, so that it has been called "the Chalky Boulder Clay," in contrast with the brown and reddish Boulder Clays of Lincolnshire and Yorkshire.

It contains flints of many shapes and sizes, lumps of hard chalk, of Red Chalk, of Carstone, and other derived fragments which have clearly come from western or north-western outcrops. Blocks and masses of chalk are also of frequent occurrence, some of them being evidently of large size.

This chalky clay was formerly dug very largely for agricultural purposes. The "marl" was used to spread, not only on the sandy and gravelly lands, but also on the loamy and gravelly soil which often covers the clay land. Mr. H. B. Woodward remarks that the "extent to which it was dug is attested by the numerous old 'marl-pits' which are to be found all over the Boulder Clay tracts, few fields being without one and many having two or more such excavations."

There is every reason to think that the Chalky Boulder Clay and its associated beds once formed a continuous sheet or mantle over the whole of the area comprised within Sheets 65 and 69 of the Geological Survey Map. It may even now form a nearly continuous sheet beneath the northern part of the Fenland and the adjoining portion of The Wash.

On the higher ground of the area, that is to say in West Norfolk, this once extensive mantle of Boulder Clay has been largely removed by Post-Glacial erosion and denudation, and this is especially the case over the western slopes of this higher ground.

Glacial Drift still mantles the greater part of the country in the south-eastern part of the district, because this tract forms a kind of table-land, and includes the water-shed between the rivers which flow eastward and northward and the shorter streams that run westward. This table-land has consequently been less acted upon by detritive agencies; nevertheless, most of the valleys which traverse it have been cut down to the underlying chalk. Farther west, however, rain and rivers have carried away so much of the Glacial Drift that only disconnected patches of it remain.

Boulders.—Isolated boulders derived from the Glacial Drift are of frequent occurrence in West Norfolk. In most cases they have simply been weathered out of the Boulder Clay or gravel in which they were originally embedded. Sometimes they still rest on Glacial Drift, sometimes they lie on the surface of the Chalk or of older beds, from which all the covering of Drift has been removed by the action of rain and running water, the boulders being too heavy for removal by such means, and too hard to have been entirely split up and destroyed by frost and sun. It is noticeable indeed that the boulders which remain are all of very hard rock, such as sandstone or quartzite; no doubt many similar boulders of chalk, limestone, and other more easily destructible rocks have been gradually broken up and destroyed by the above-mentioned subaërial agencies.

The following notes refer to the position and characters of some of these boulders :—

MR. WHITAKER observed that in two old pits, one about a mile and the other three quarters of a mile westward of Roydon Church, there were two boulders of hard Neocomian sandstone [greenish-grey glauconitic stone], one, measuring $7\frac{1}{2} \times 6\frac{1}{2} \times 2$ feet, of a roundish shape, with the top surface ground flat and coarsely scratched. In the other the sandstone is fossiliferous, and contains phosphatic nodules, the block measuring about $6 \times 4 \times 1\frac{1}{2}$ feet.

The same observer noted, about two thirds of a mile N.N.W. of Congham Church, between road and railway, a boulder of Millstone Grit, measuring about $4\frac{1}{2} \times 2\frac{1}{4}$ feet, and showing about $1\frac{3}{4}$ above ground, the rest being embedded in the soil.

MR. WOODWARD observed a large quartzite boulder in the Boulder Clay of the railway-cutting between Massingham and Rudham Stations.

He also saw two large boulders of quartzite to the north of the Black Swan Inn at Creake, one of which measures $4 \times 3 \times 2$ feet.

Mr. REID measured a boulder of basalt by the road-side at Choseley, north of Docking, and found its dimensions to be $4 \times 2 \times 1\frac{1}{2}$ feet.

Details.

In dealing with the notes of local exposures in the Boulder Clay and brick-earth, it will be convenient to begin with the area adjoining the southern border of the sheet, and to take first the tract which lies south of Castle Rising.

Castle Rising.—An irregular patch of Boulder Clay, with some gravel in the midst of it, stretches from the town to Rising Lodge, and thence along the hill-top towards Roydon. This was mapped by MR. WHITAKER, but the only exposure he found was in a gravel-pit (see p. 80).

There are several small patches of Boulder Clay near Roydon, and two others near Hillington. MR. WHITAKER contributes the following notes on exposures near Hillington, Anmer, and Massingham :—

Hillington.—In an old pit on the north of a barn about half a mile N. of E. from Hillington Church, the northern and clearer end showed, in 1882, hollows of very stony Boulder Clay over buff loam and sand; a lower part showed the buff loam with Boulder Clay apparently rising up from beneath (but this may be a deep continuation of one of the hollows). The southern part seemed to be in Boulder Clay and Chalk-rubble. There were boulders of fossiliferous Neocomian Sandstone, with phosphatic nodules.

Anmer.—At the triangular Common E.S.E. of Anmer, there is a set of old pits, in a slight hollow, and clearly dug for buff and pale grey loam or sandy clay, which must have been largely worked for bricks. It is probably of Glacial age. There was an exposure of the loam at the south-eastern part

of the patch mapped, and loam or sandy clay was also seen beyond the Common on the north-western side of the higher road. The boundary is made doubtful by the drifted sand, which hides everything.

There is another large patch of Boulder Clay south of Anmer, and in a pit just southward of the barn, on the hill-top, about a mile north-eastward of Flitcham, the southern side gave the following section (1882) :—

Sandy and loamy soil.
Whitish, very chalky, Boulder Clay.
Pale gravelly sand, at one spot to about 2 feet.
Chalk with flints, at the bottom of the pit.

On the western side, sand, partly gravelly, was seen to come on over the Boulder Clay, and toward the north there is a thickness of about 10 feet of it. The eastern side was overgrown, and very little of the pit was clear.

Another old pit, in a field north-westward of the farm, showed little Boulder Clay (really a marl), irregularly piped by brown loam and sand, with flints, clearly the result of decalcification. Probably here, also, chalk was found beneath.

In an old pit over half a mile north-eastward of Anmer Church, a like section was seen to those just described.

In an old pit in a field a little south-east of Ling House, north of Anmer, was seen whitish sandy chalky Boulder Clay, decalcified at top, where it is penetrated by brown sand with flints. It looks as if chalk with flints had been found beneath.

Another old pit, in a field just north-east of the same house, showed like earth (sandy), up to eight feet thick, over soft white rubbly chalk.

At another, just south of the lane, not half a mile east of that house, I could not well make out the beds. There seemed to be little of the Boulder Clay piped into rubbly chalk ; and the Chalk probably comes up near to the surface.

At yet another pit, by the hedge marked on the map, about a third of a mile northward, chalk with flints (weathered at top) comes to the surface on the southern and lower side, whilst on the north there seems to be a little of the Boulder Clay.

Little Massingham.—At the brickyard there was in 1882 a shallow pit with water, just south of the church, showing loam and sandy clay, weathered brown at top and with flints, the lower part being grey and with fewer flints. In many parts (south) only the brown earth was to be seen. Judging by the earth thrown out a well has been carried through whitish Boulder Clay into chalk (see p. 120). The most southerly pit was in light brown and grey loam, with few stones.

A pit on the eastern side of the Peddar Road, nearly a mile west of Little Massingham Church, showed a tiny patch of pale sandy chalky Boulder Clay, passing off into rubble, over chalk with flints. A fault was shown by a continuous layer of thick flint at the bottom. W. W.

Great Massingham.—South of Upper House and a mile and three quarters east of Great Massingham, MR. WOODWARD saw a pit opened in Boulder Clay, and north-east of the House another pit showed a "jamb" of disturbed chalk in a loamy and flinty deposit consisting partly of reconstructed chalk with knobs of hard chalk and chips of flint.

In the cutting north-east of Rudham Station, MR. WHITAKER saw a long detached mass or boulder of chalk.

The Massingham tract of Boulder Clay was of course originally continuous with that round Harpley, and this again with that north of Houghton and Rudham, but they are now separated by narrow valleys which are cut down into the underlying Chalk.

The following notes are by MR. H. B. WOODWARD :—

Harpley and Rudham.—Around these places the Boulder Clay is frequently covered by a loamy and sandy soil with flints. This soil sometimes becomes so gravelly in appearance that it is not easy to decide from surface evidence whether or not it should be mapped as a gravel.

Rather more than a quarter of a mile north of East Rudham Church, a clayey soil with flints has been dug for making bricks, and bricks were also made from a similar soil south-west of Harpley Church.

At Rudham the clay contains much hard chalk, and occasionally strips or masses of chalk, also large flints or "paramoudras," and pieces of iron-sandstone (Carstone).

Bircham.—At Great Bircham there are two brickyards, one west of the town, in which MR. REID saw about 10 feet of stony loam and laminated clay without stones, apparently overlying about 3 feet of chalky gravel, but the whole was very irregular.

At the brickyard east of the town, MR. WOODWARD found ordinary Boulder Clay dug for brick-making, and saw a contorted mass of sand which appeared to rest on the clay and to be connected with the patches of sand and gravel that occur in the neighbourhood.

Barmer and Syderstone.—MR. WOODWARD mentions a pit south-east of Barmer Church, which showed four or five feet of Boulder Clay resting on much disturbed and partly reconstructed chalk; on the south-west side of the pit there was some sand and gravel. He also saw, in 1883, the section represented in Fig. 6, in a pit near Syderstone, and remarks that "There was evidently a piped surface of Chalk prior to the accumulation of the Boulder Clay. The 'pipes' or pockets are known locally as 'golts' of sand and gravel, and these were truncated at the surface and portions of the gravel and sand were incorporated with the Boulder Clay during its formation. The Boulder Clay itself has subsequently been decalcified and 'piped,' and in one instance (on the left side of the section) the newer pipe has merged downwards into one of the earlier pipes in the Chalk. The Chalk itself was glaciated, being much broken up, while the flints were shattered."

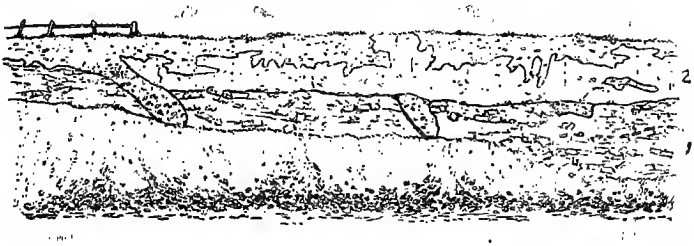


Figure 6. Section at Syderstone.

(H. B. WOODWARD.)

Length about 2 chains. Height 16 feet.

2.—Chalky Boulder Clay, piped, with upper part decalcified.

1.—Chalk with flints, blocky, and much disturbed by glacial action. It contains pipes of sand and gravel, lined in places by dark brown or black clay.

Docking.—The following notes on the Boulder Clay near this place are furnished by MR. BARROW :—

Between Bircham Newton and Docking the clay contains many large lumps and blocks of ferruginous sandstone full of fossils (? Carstone). It also contains lumps of hard chalk and rounded flints.

North-east of Bircham Newton and about three quarters of a mile south of Docking Lodge is a pit showing the following sequence :—

Decomposed chalky clay with a clearly marked base-line.

Fine sharp and clean sand, apparently more than 10 feet.

Chalky Boulder Clay seen below at one side.

At Docking Lodge a pit shows chalky Boulder Clay overlain on the south side by five or six feet of bedded sand and gravel.

A pit three quarters of a mile south of Docking Lodge showed the following succession :—

Chalky Boulder Clay.
Fine sharp sand, over 10 feet.
Chalky clay seen below.

At the pit on the south side of Docking the clay was so free from stones that it was spoken of as brick-earth ; at the entrance to this pit the clay rests on coarse gravel, or more probably a seam of gravel occurs in the clay, the gravel consisting of hard rounded flints and pebbles of hard chalk.

In two pits near Stanhoe the clay is of a yellowish-white colour, and in one case a seam of coarse sand occurred in it.

Just north-east of Docking there are two pits which intersect a transported mass of chalk. It is steeply inclined to the west, and has Boulder Clay both above and below it, but is thinner in one pit than the other. The line connecting the exposures runs N. 10 W. and S. 10 E. G. B.

MR. REID contributes the following notes on sections seen by him near Docking :—

A pit one mile W.S.W. of the church showed about 15 feet of bedded chalky Boulder Clay with scarcely any other stones than chalk and flint.

Another pit a quarter-mile south-east of the last showed—
Boulder Clay two feet.
Glaciated [? reconstructed] chalk eight feet.
Chalk with flints.

A quarry about a quarter of a mile north-west of the church is in chalk, and has been mapped as if it showed chalk in a normal position, but MR. REID records that it has a dip of 60° to the E.S.E ; consequently it is most probably a transported mass like that seen in the pits north-west of the village. The chalk here exposed contains both scattered nodules and layers of flint, and is overlain by about two feet of brown chalky rubble.

An old pit on the Heacham road one mile from Docking exposed four feet of hard sandy loam with angular stones (apparently decalcified Boulder Clay) overlying eight feet of very chalky Boulder Clay. C. R.

East of Docking, round Stanhoe, and thence to the edge of the Creake and Burnham Valley, as well as northward toward Brancaster, there is a broad spread of Boulder Clay. Few notes respecting it have come into our hands, but it would appear to have everywhere the usual characters of the chalky and stony type of Boulder Clay already described.

Sedgeford.—West of Docking there is a considerable tract of gravel (see p. 84), but towards Sedgeford Boulder Clay is again found, and on the hill east of the village there is a separate tract consisting partly of brick-earth and partly of Boulder Clay capped by a patch of gravel. Of this tract Mr. WHITAKER furnishes the following notes :—

About a third of a mile east of Sedgeford Station, on the north of the railway and on the east of a lane not marked on the map, and touching both, is an old pit and pond, showing pale grey and buff fine sandy clay or loam, in parts with some very small chalk-pebbles, apparently a sandy Boulder Clay. There are two other old pits opposite, one on the west of the lane, the other on the south of the railway, overgrown, but presumably in like earth, all these pits being in the little wood. The little cutting just westward was overgrown, but chalk was turned out at a telegraph-post.

A little way south of the railway just west of the next road to the east, from a farm, is a larger old pit and pond, showing stiff grey clean clay.

Above, or south of, the farm, which is on the eastern side of the road, is a pond overgrown, but showing some buff sandy Boulder Clay, like that in the pit to the north-west, just noted. W. W.

Brancaster Field.—Mr. A. C. G. CAMERON reports that the clay on the high ground south of Brancaster and Burnham Deepdale is mostly of the light-coloured chalky type. Thus a pit on Barrow Common showed a fine

whitish chalky clay at the top with little but chalk in it, and below was a bluish clay with many stones and boulders. Another pit near by was 10 feet deep in a greyish Boulder Clay with large pieces of chalk, large scratched flints and other stones ; at the top are two feet of clayey gravel (? weathered Boulder Clay soil).

He mentions another pit about three quarters of a mile south of Burnham Deepdale as exposing "Boulder Clay which is red in the upper part and white below, and has numerous flints in it." If the red clay here is like the reddish (Hessle) clay of the low ground near Brancaster this section may be of some importance as showing the superposition of that clay on the chalky clay.

MR. CAMERON also mentions a pit just south of Moodie Cottage, Burnham Sutton, in which he saw a sandy marl with contorted beds and a gravelly base overlying very chalky Boulder Clay which seemed to pass under a mass of chalk or chalk-rubble. Here, again, there seems to be a newer deposit (? of Hessle Clay age) resting on the (? older) chalky Boulder Clay.

A. J. J.-B.

CHAPTER 7. GLACIAL DRIFT (*Continued*).

GRAVEL AND SAND ASSOCIATED WITH CHALKY BOULDER CLAY.

The gravelly and sandy deposits associated with the chalky Boulder Clay are difficult to classify. In this area such deposits for the most part overlie the clay, but they occasionally underlie it, and are in some cases clearly interbedded with it. There are also isolated patches of gravel which are not now in contact with Boulder Clay, but which from their position and character appear to be of Glacial age and have been coloured as Glacial gravel on the map.

These gravels and sands present all degrees of coarseness from a fine sand to a coarse sand with scattered stones, and from a fine gravel to a deposit of large stones and boulders. As a general rule their materials have been principally derived from the Chalk, sometimes they consist almost entirely of rolled chalk pebbles, in other cases of such pebbles mixed with flints in varying proportion ; even the sands are generally composed of fine chalk and flint *débris*. A careful search, however, generally discovers some travelled stones, and these have usually come from sites to the westward or north-westward. Thus, on the Lower Greensand area lumps of Kimeridge clay are common in the Drift, and on the Chalk area pieces of Carstone and Red Chalk occur. There are also fragments of sandstone and limestone which have come from the north or north-west, and some of basalt, but these are rare.

Details.

In describing local details, it will be convenient to begin as before near Castle Rising, and the following notes on that district and the adjoining area to the eastward are by MR. WHITAKER.

Castle Rising.—Gravel rises from beneath the eastern end of the patch of Boulder Clay, south of Castle Rising. There is a pit at the edge of the wood rather more than three quarters of a mile south-west of the church. When seen in 1881, the southern end of the eastern face showed a trifle of whitish Boulder Clay, over about eight feet of bedded grey brick-earth, with a layer of chalky gravel at about the middle. The beds rose northward, and were then lost, chalky sand and gravel rising up from below ; but farther on the gravel was again capped by a little of the brick-earth, also chalky, to the thickness of nearly three feet at the north, and there are also traces of Boulder Clay at top. A thickness of eight feet of the gravel was shown at one place ; but all the lower part was hidden by fallen earth. The uprising of this gravel from beneath the bordering Boulder Clay is shown by a small spot of colour on the map.

Still farther south is a larger patch of gravel, which also passes beneath Boulder Clay to the south-eastward. Gravel has been dug in it west of Rising Lodge.

Babingley.—North of the Babingley River there are two irregular patches of Glacial gravel ; one about a mile in length north-east of Babingley appears to rest directly on the Lower Greensand, the other on a hill south of West

Newton overlies Boulder Clay and brick-earth. Gravel has been dug at both places.

The patch of gravel north-eastward of Babingley varies greatly in level; but seems to be continuous from end to end. The possibility of a little clay occurring beneath it has been alluded to (p. 94).

Just west of the sixth milestone, on the high-road, was a pit, 12 feet deep, in gravel and sand, with small boulders of dark grey laminated fossiliferous clay (probably Kimeridge) in the lower part, and, near the bottom, with a layer of pale grey clay at one part. The gravel is chiefly of flints.

Westward of the hill-top is a line of old pits in the gravel and sand, from the Sandringham road to the high-road.

West Newton.—On the Common on the hill-top (about a mile W.S.W. from West Newton Church) there was another set of pits showing gravel and sand, to a thickness of 15 feet. The gravel here consists chiefly of flints and of chalk-pebbles (of various sizes), with some ferruginous stone from the Lower Greensand, and it is partly coarse, partly fine, and irregularly bedded.

On lower ground just by (E.S.E.) were other pits in sand and flint-gravel, to the depth of about 10 feet at one spot.

In the patch south of West Newton there was, in 1882, a gravel-pit near the top of the hill, about three quarters of a mile south of West Newton Church; the face was mostly hidden, but at the southern end I saw a few feet of current-bedded sandy gravel, chiefly of flints, and with some pieces of ferruginous stone from the Lower Greensand. To the north, on the eastern side, and at a lower level there was buff sand to over five feet thick, above gravel, chiefly of hard chalk-pebbles (which are rare in the other part) and flints, to a depth of seven feet. The sand occurred only on the east.

At an old pit, just north-west and close to the plantation, there seemed to be some Boulder Clay, at all events, whitish clayey earth of some sort, as also at another old pit toward the western part of the hill, and westward of the same plantation.

Hillington.—At and near this place there is a tract of Glacial deposits consisting of Boulder Clay, loam, gravel, and sand, much intermingled. An old pit, about 15 feet deep, in the small round wood, marked on the map, two thirds of a mile south-eastward of Hillington Church, showed, in 1881, a sort of gravel, composed chiefly of pebbles and blocks of chalk, tightly packed; with many blocks of dark grey clay (? Kimeridge), full of indistinguishable shells, and some boulders of chalk and of a few other rocks. This was seen to be roughly bedded, with sandy layers (full of chalk-grains), and near the middle to contain an irregular bed of loam, in great part marly and tough, and partly with chalk-grains, which rose to the surface at the south. The top part of the gravel is clayey in places, and the very little of this seen would do for very stony Boulder Clay.

At a later visit (1883) the underwood having been cut down made the section clearer, and some large boulders of chalk and large lumps of the clay were seen. The material was about the most jumbled-looking in the district, a sort of Boulder Clay less the clay. W. W.

Between Hillington and Massingham.—Another tract of gravel with some Boulder Clay on its southern side lies on the high ground, about two miles east of Congham. Of this MR. WHITAKER observed:—

In the pit, marked on the map, on the northern side of the road, $2\frac{1}{4}$ miles east of Congham Church, there is, at top, three feet or more of rubbly earth, with flints (chiefly in the bottom part). At the north this expands into a hollow of Drift, consisting of traces of light-coloured sandy Boulder Clay at top, in parts, and gravel, mostly chalky, with a layer of irregular iron-sandstone. The chalk beneath, shown to a depth of about 15 feet, is singularly broken up, being composed of lumps of all sizes (up to nearly two feet in length), and of less hardness than the chalk at lower horizons, in a softer matrix. There is an irregular layer of flints in the lower part, and there are other flints in places above. At the south (overgrown) there are also traces of the Drift-hollow, which must run about north and south across the pit, and with more decided Boulder Clay.

An old pit on the northern spur of this hill, nearly a mile south of Harpley Dam House, was also examined in 1882; the lower part was hidden, but a thickness of about seven feet of gravel was seen. This consisted chiefly of chalk-pebbles, except at the top, where the chalk has been dissolved away irregularly, leaving the other stones in brown sand; there are also flints, some pieces of ironstone from the Lower Greensand, and a good many small dark nodules, like the phosphates of that formation. Two fair-sized boulders, apparently of Neocomian Sandstone, were seen—one at the bottom of the gravel, the other lying in the pit.

An old overgrown pit a little W.S.W., marked on the map, showed gravelly earth at top, and there are other signs of the like, which led me to map gravel over the hill-top instead of only over the northern spur, as I was at first inclined to do.

There are several small patches of gravel on the southern slope of the valley along which the railway is carried, and in one of these, about half a mile W.N.W. of Little Massingham Church, a pit in a little wood showed soil and gravelly patches overlying brown and buff sand, with a few gravelly layers, the total depth being up to 11 feet. W. W.

The following notes on the tracts of gravel in the south-eastern corner of the area are by MR. H. B. WOODWARD :—

Kipton Heath.—The tract of gravel which comes to the surface on Kipton Heath passes eastward beneath Boulder Clay. A pit south of Kipton Ash Fair Place showed chalky Boulder Clay resting on pale buff and white chalky sand, with much current-bedding, and with layer of small chalk-pebbles here and there. About seven feet of this sand was visible. By the railway, west of Kipton Heath, a pit showed alternations of buff and brown sand ten feet in thickness, with a gravelly soil on the top. On the Heath gravel has been dug.

Tatterset stands on gravel, which also probably passes beneath the Boulder Clay of the higher land to the eastward. A large pit by the side of the high-road at Tatterset showed the following section :—

	Feet.
Reddish flint gravel, some large flints	6
Sand, with seams of loamy clay, somewhat contorted	? 1
Pale buff-coloured gravel composed of chalk and flint, with some large boulders of flint...	12 to 15

The different appearance of the two gravels is no doubt due to the solution of the chalk and the oxidation of the iron in the upper bed, while the lower gravel has been protected from such alteration by the intervening layer of loamy sand and clay.

Syderstone.—On the high ground south of Syderstone, forming Rudham and Syderstone Commons, there is a large tract of gravel, and a pit on Rudham Common exposed about 18 feet of coarse gravel, composed mainly of flint and chalk-stones, with some patches of Boulder Clay. There is similar gravel south-east of Wickend Farm, but north-eastward, near White Hall, there is sand.

Houghton.—Another tract of sand and gravel lies on the Chalk to the north of Houghton, and a pit half a mile north-west of Houghton Hall showed white and buff sand, with some gravel resting on Chalk. Over a large part of the Houghton estate the soil is very light and sandy, especially to the west of the Hall, but in many places the old pits show that chalky clay or Chalk was reached at no great depth.

Harpley.—On Harpley Common and to the south-east of it there is much coarse flint boulder-gravel, composed of large rounded flints, shattered flints, ironstone nodules, and a few quartzite pebbles in a brown loamy sand, the whole very irregularly arranged. H. B. W.

MR. WHITAKER has the following note on sections here :—

An old pit in a field just west of the hill-top, and over a quarter of a mile north-eastward of Harpley Dam House, showed, in 1882, coarse gravel, with

a matrix of brown loam. It was chiefly composed of rather large flints, with many pieces of ferruginous stone from the Lower Greensand. At one part a lump of buff sand came abruptly up to the surface.

Another old pit a little northward, in the next field, showed at the top (the rest being hidden) a little mixture of chalk, flints, and chalky sand (? the bottom part of the gravel), with chalk apparently close below. W. W.

West of Wash Meres a pit showed coarse gravel and Boulder Clay resting on Chalk. Another patch of coarse "cannon-shot" gravel occurs to the northward about half a mile north-east of Bircham Heath Farm, and a pit here exposed about 15 feet of such material. Large *paramoudras* were seen here, and one measured two by two feet, having an irregular cavity extending about three parts of the depth.

Bircham.—On Bircham Common is another large tract of sand and gravel which appears to overlie Boulder Clay, and a tongue of this extends north-eastward to Bagthorpe. A pit by the wood south of Bircham Tofts showed 12 feet of buff sand, with seams of chalky gravel and a covering of gravelly soil.

In the brickyard east of Great Bircham Church there is sand which, although included and contorted with the Boulder Clay, appears to be connected with the sand and gravel that spreads over much of the district to the southward. H. B. W.

West of Great Bircham there are several patches of gravel in and below the Boulder Clay, and at Bircham Newton, a quarter of a mile south-west of the church, was a pit in a kind of gravel which MR. REID describes as rounded chalk rubble, with foreign pebbles passing down into angular chalk rubble, with nests of sand.

Docking.—A large irregular tract of gravel occurs near Docking, spreading to the west, north, and south of the village. About three quarters of a mile south of the church is a large gravel-pit, of which MR. BARROW furnishes the following note:—The gravel here consists of great boulders of hard chalk and flint mixed with finer material, and is remarkably well bedded. It rests against a steep face of chalk, and it appears to pass under the Boulder Clay. I could not see this in the quarry, but the man there assured me very positively that it did. I hunted a long time but could find no shells. The finer material consists chiefly of fine flakes and grains of hard chalk; the great amount of which makes the whole dazzlingly white in the sun.

MR. BARROW contributes the following notes respecting the long strip of gravel which follows the road from Docking to Syderstone. It extends for about two miles to the south-east, and then turns to the west towards Bircham, and keeping north of Bagthorpe forms a small strip along the Bircham and Syderstone road. As a rule this gravel consists of rather large rounded lumps of flint and sometimes hard chalk, in a matrix of coarse sand. It is subject, however, to considerable local variation. In one of the western pits on Docking Common it consists mostly of broken angular-looking flints, rounded ones being uncommon. At the southern end of the Common is a bed of fine, clean red sand in the gravel, the latter, however, shows no bedding.

When this gravel comes nearest to Little Barwick it presents a curious character. It has been so firmly cemented together by iron that blocks of it have been used in building several cottages in the immediate neighbourhood.

The other little patches of gravel mostly call for no particular notice. The one near Docking Lodge looks suspiciously like a decomposition product of a very stony clay; but the farmer assured me that in the wood it went to a considerable depth; and the fact that there are no marl-pits in it, seems to show that it must be a distinct deposit. G. B.

The tongue of gravel which runs northward from Docking seems to be in a hollow of the chalk which comes up to the surface in the railway-cutting west of the Station. MR. WHITAKER referring to this cutting remarks that it is now overgrown, and the junction of the Drift with the Chalk is concealed. On the southern side of the cutting, however, he saw a little buff sandy Boulder Clay overlying buff sand with thin layers of Boulder Clay near

the top; the sand goes down below the level of the rails, the depth of the cutting being about 18 feet.

Farther west, and south of Summerfield, is a small patch of gravel in which there is a large pit. MR. REID saw here, in 1882, 20 feet of coarse gravel consisting almost entirely of chalk and flint stones, well rolled, and resting upon Chalk.

About a mile N.N.W. of Summerfield is another patch of gravel associated with a tract of Boulder Clay, and still farther north, near Thornham Ling, is an oblong patch of gravel resting on Chalk. The following note by MR. WHITAKER relates to this locality :—

An old pit in a field a little south-east of Thornham Ling was in very irregular chalky gravel, with at one part what may be called a chalk-grit, and at another part with chalky sand. At the clearest (western) part the gravel was seen, in 1883, to contain many very large flints, more or less rounded and pounded, and to be associated (? interbedded) with some buff sandy Boulder Clay. There were a few small pieces of Red Chalk, and a block of Neocomian sandstone with shells and phosphatic nodules (? from Lincolnshire). At another part the Boulder Clay was seen to cut obliquely over the gravel ; but other gravel may come on above. The whole deposit looks Glacial.

Sedgeford.—The gravel which caps the hill east of Sedgeford was mentioned on p. 78 ; the following notes respecting it are by MR. WHITAKER. At its western end about a mile E.N.E. of Sedgeford Church, and in a narrow enclosure bordering the western side of the lane leading northward was a small pit, some eight feet deep, in brown sandy irregular gravel containing many large flints (some splintered into many fragments), pieces of ferruginous stone from the Lower Greensand, and what seem to be some small pieces of Red Chalk. At the farm to the east there was a pit, showing over six feet of brown gravelly sand, just above the large pond to the north, which is in Boulder Clay. This patch of gravel seems to rest partly on Chalk and partly on Boulder Clay and loam. W. W.

In the valley south-east of Sedgeford a series of small patches of gravel and sand have been mapped. One of these abuts against the chalk exposed in the quarry, about 350 yards south-east of the church. It is described by MR. CAMERON as consisting of sand and gravel partly coarse and partly fine, with a wedge-shaped bed of sandy loam or brick-earth. The gravel consists of chalk-pebbles, flints, lumps of Carstone, and a few of Red Chalk, and appears to rest on a stony Boulder Clay the base of which was not seen.

The last of this series of gravelly patches is one which extends from Fring Wood to the ground on which Fring Church stands. Gravel is dug in Fring Wood, and MR. CAMERON supplies the following note of the section :—The sand and gravel are very irregularly interbedded, but the face exposed in 1883 may be described as showing coarse gravel including an irregular bed of sand, the base of the gravel resting on a sloping surface of coarse, yellow laminated sand.

Several patches of gravel have been mapped to the east of Sedgeford, but no notes of any exposures have come into our hands.

Another small tract occurs on the slope of the hill near the farm called Horsewell, north of Snettisham. Gravel was being dug from this in 1875, and was seen by MR. JUKES-BROWNE, who noted the material as coarse gravel with irregular patches of sand, the stones were chiefly rolled flints and chalk-pebbles, probably more than 50 per cent. being of chalk.

Syderstone and Creake.—Several patches of sand and gravel have been mapped to the east and north of Syderstone, and others west of South Creake, and these seem to be lenticular strips intercalated in the Boulder Clay. (See p. 77.)

Burnham.—On Gallow Hill, south of Burnham Westgate, there are several tracts of gravel. Half a mile south-west of the church are two pits, of which MR. CAMERON reports as follows :—The first pit is from 25 to 30 feet deep, and shows alternations of coarse and fine flint gravel in a sandy matrix ; at the bottom the stones are large and well rounded, resembling

cannon-shot. Another pit to the eastward shows similar gravel at the top, but partially grown over; underneath it and well exposed for 13 feet is clean chalky marl, *i.e.*, chalk churned up into a pasty marl that cannot be truly called clay for it probably has 90 per cent. of carbonate of lime. The total depth of the pit is about 25 feet.

Brancaster.—Gravel associated with chalky clay is again found on Barrow Common, south of Brancaster. The following notes are by MR. CAMERON :— A pit on the northern edge of the Common showed alternations of gravel and sand, thus—

	Feet.
Gravel	3
Coarse yellow sand ...	2
Gravel	2
Fine yellow sand ...	2

Another pit showed an equal depth of current-bedded gravel and sand, rather ferruginous and made up chiefly of angular flints and pebbles of grey and red sandstone. A. C. G. C.

CHAPTER 8. GLACIAL DRIFT (*Continued*).

THE BROWN BOULDER CLAY AND ITS ASSOCIATED DEPOSITS.

The Boulder Clay which borders the northern coast differs from that which covers the chalk to the southward, and closely resembles the upper brown Boulder Clay in Yorkshire and Lincolnshire, which was called the Hessle Clay by MR. SEARLES WOOD, Junr.

This clay of the northern border is generally of a reddish-brown colour with grey streaks and mottlings, and has fewer stones than the ordinary grey chalky clay. It has much less chalk in it, only small scattered pellets or pebbles of chalk, and fewer flints ; the commonest stones after these being fragments of basalt, of quartzite, and of red and yellow sandstones. In some places it includes or passes into a brown sandy brick-earth. There are also associated beds of gravel and sand.

Whether these brown clays and brick-earths are really a distinct formation of either earlier or later date than the inland chalky Boulder Clay is a question which has not yet been decided. MR. WOODWARD was unable to separate them in the sheet to the east (68) from the clays and loams of the Contorted Drift Series, but in Lincolnshire they have been regarded as more recent than the chalky Boulder Clay. In this sheet (69) MR. CAMERON has seen one case in which a reddish clay overlies a whitish chalky clay (see p. 79) ; but, on the other hand, MR. REID observed that on the foreshore near Brancaster the red passed laterally into grey clay.

The following notes by MR. WOODWARD relate to the country near Burnham Overy on the eastern border of the map :—

The surface soil over much of the country between Holkham (Quarter Sheet 68 N.W.) and Burnham Overy is a brown loam. In the Holkham Brickyard the earth worked is a mottled brown and grey stony loam or Boulder Clay with only a few stones. Before this pit was opened up bricks for the Holkham Estate were manufactured at Burnham Norton.

Just east of Burnham Overy Watermill is a pit showing sand over brick-earth. Farther east, brown loam was exposed in the ditches and in the railway-cutting, and overlying this to the north were patches of gravel and sand. The boundaries between the chalk and brick earth north and north-east of Burnham Overy are vague, but the soil was so loamy that I could not hesitate to show the brick-earth as occurring continuously to the Alluvium east of Overy Staith. BACON has remarked that "From Holkham Park West Gate, right and left of the road to Burnham Market, the soil is deep and of fine quality, upon which as much as eight quarters per acre of barley have been grown."*

North of Pinkney Hall a small excavation by the Alluvium showed about five feet of brown loam resting on three feet of stiff blue and pale brown mottled clay. Farther north a brickyard has been opened in the loamy soil on top of the Boulder Clay. H. B. W.

Associated with this brown Boulder Clay are several tracts of sand and gravel. MR. WOODWARD writes :— There are deposits of sand and gravel which stand out as prominent mounds or hills in the country round Burnham

* "Agriculture of Norfolk,' p. 15.

Overy. One of these, near Overy Staith, forms a tract about half a mile long by a quarter of a mile wide, and a pit was opened in it south of the Staith, but the gravel found was too sandy to be of much use.

East of Overy water-mill a pit was open in sand, and farther east a small outlying hill like a barrow seems to be formed of loam covered by a slight gravelly capping. H. B. W.

Referring to the Holkham brickyard, MR. CAMERON remarks that although the clay is sufficiently free of stones when washed to be used as brick-earth, there are stones in it which have to be picked or washed out. Judging from a heap of these in the yard, the bulk of them are subangular fragments of limestone, small boulders of basalt, pebbles of sandstone, and quartzites from Triassic deposits.

About half-way between Burnham Westgate and Burnham Deepdale there is a deposit of brick-earth which was worked for a long time. MR. CAMERON found three pits here in 1882; one showed reddish unstratified clay, containing small stones and occasional seams or "flashes" of gravel. This clay is 4 or 5 feet thick, and rests on a sand which is full of small pebbles of chalk. The next pit (west of the first) was disused, but exposes about 9 feet of fine, brown, sandy loam, containing calcareous concretions which are called "ginger" by the workmen. A third pit, south of the above, showed the following succession :—

	Feet.
Stony clay and gravel, with a variety of pebbles, resting unevenly on the loam below ... from	0 to 3
Fine, clean, brown, sandy loam (brick-earth) „	5 to 8
Fine gravel and sand, very chalky, base not seen	2

The loam or brick-earth which occurs in two of the pits is too "mild" for use by itself, and is consequently mixed with the stronger red clay found in the first pit. A. C. G. C.

These brickyards are now abandoned and obliterated.—G. W. L. 1898.

The section south of Burnham Deepdale, where red clay was seen overlying white chalky clay, has been mentioned on p. 79.

A long continuous tract of the reddish-brown Boulder Clay runs all the way from Brancaster to Hunstanton, a distance of six miles. It forms a sort of terrace between the marshlands of the coast and the slope of the bare chalk-land above. This Boulder Clay extends under the marshland, and is probably banked up against a steep slope or cliff of chalk on the south, just as the brown Boulder Clays of Lincolnshire are banked up against the buried cliff-line of the Lincolnshire Wolds.

MR. REID noticed that in Brancaster Bay at low water of spring tides the Boulder Clay was seen on the foreshore underlying the "submerged forest." Most of the clay was of a brown colour, like that of Hunstanton, but for a short distance this clay passed both laterally and vertically into lead-coloured, very chalky Boulder Clay.

The eastern termination of this strip of clay is concealed by a superficial deposit of gravel which stretches from Burnham Deepdale to Brancaster. At Thornham and Holme the width of the clay strip is more than half a mile on the average. It runs for a short distance up the valley of the little stream at Old Hunstanton, and is also found on the western side of the alluvium between the sand-dunes and the chalk-cliff.

This continuous strip of Boulder Clay resembles the Hessle Clay of Lincolnshire and Yorkshire, not only in its colour and general characters, but also in the geographical position which it occupies; intervening as it does between the sea-bord marshes on the one hand, and the higher Chalk-land on the other. In the two more northern counties the Boulder Clays appear to be banked up against an ancient coast-line, and the line of junction often coincides with a concealed line of cliffs. The continuous boundary of the Hessle Clay along the tract above mentioned and the abrupt termination of the clay against the inland slope of Chalk, suggests that there is a similarly concealed coast-line along the northern border of Norfolk, and that the relative positions of Chalk, Boulder Clay, and Marshland are as represented in Fig. 7.

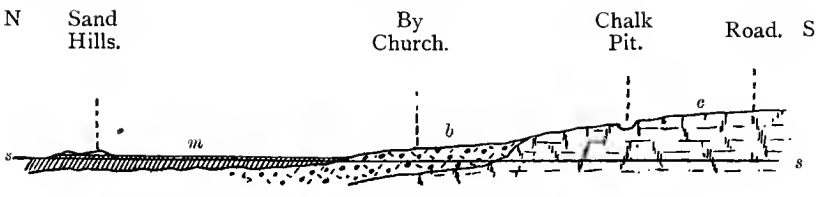


Figure. 7. Section through Holme. (JUKES-BROWNE.)

Scale, 2 inches to one mile.

c = Chalk. m = Marsh beds.
b = Boulder Clay. ss = Sea-level.

MR. LAMPLUGH supplies the following note on a section recently observed by him at the north-eastern termination of the Chalk Cliff at Hunstanton :—

I noticed at this place, in 1895, that the Chalk ended abruptly in a low cliff, against which chalky rubble was banked, reminding me somewhat of the buried cliff at Sowerby in Yorkshire.

On re-examining the section, however, during my recent visit to Hunstanton (June, 1898), I found that the blown sand, which hides everything beyond this point, had suffered further erosion, revealing a somewhat clearer section. The Chalk ends off, as I had previously seen, in a steep cliff-like slope about 18 feet high, but reappears 12 yards farther east, with a similar slope facing in the opposite direction, only the lower part of which is at present uncovered, consisting of red chalk, capped with the Sponge and Inoceramus beds. The interval between the two opposite slopes is still partly obscured by blown sand, but appears to be filled up entirely with somewhat subangular chalky wash or rubble, in which the only extraneous substance which I could detect was a small pebble of quartzite. We seem here to have a section across a shallow valley in the Chalk, such as are frequently revealed in the Flamborough Cliffs in Yorkshire. The course of this valley can be traced inland by a slight depression of the surface; it runs southward, nearly parallel to the present cliff. A better section will, no douht, be afforded in the future, as the erosion of the dunes at this place is still in progress. G. W. L.

By the road south of Old Hunstanton Church is a small patch of Boulder Clay, and to the east of it, behind the Hall Gardens, is a small pit in sand and gravel in which MR. CAMERON found some shells—*Astarte sp.* and *Cyprina islandica* (?). The relation of the sand and clay was not determinable.

Between Hunstanton and Ringstead there are several small patches of gravel and sand which may belong to the Hessle Clay group, especially as some of them contain marine shells. One of these patches occurs in the Park about a quarter of a mile south of the Hall, and two others lie on the S.E. border of the Park. MR. WHITAKER observed a curious "Esker"-like ridge which commences in the south-western part of the Park, and after making two sharp serpentine bends, passes out of the Park in a southerly direction, and then curves round toward Ringstead St. Peter, terminating above the valley which runs westward from that place.* At the southern end of this ridge there is a pit where MR. CAMERON noted sand and gravel 6 feet, with 3 feet of sand beneath. The stones include many chalk-pebbles, both of hard white and red Chalk, a few flints, and some angular fragments of a dark-coloured igneous rock with garnets. MESSRS. WHITAKER and REID found some fragments of shells at this place.

At the southern end of the Hunstanton cliff the Carstone is overlain by a variable thickness (10 to 18 feet) of Hessle Beds, mostly reddish-brown

* This "Esker" was regarded by Carvill Lewis as portion of an old sea-beach. *Papers, &c., on Glacial Geology*, 1894, p. 340. See also T. V. Holmes, *Geol. Mag.*, 1883, p. 438.

Boulder Clay, but containing lenticular beds of sand, and having a gravelly layer at the base, where it rests on the Carstone.

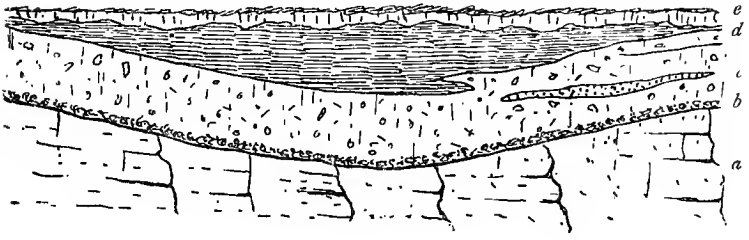
The earliest notice of this Drift seems to be that by MR. ROSE, in 1836,* who says :—"Beyond the point where the incumbent *red chalk* crops out I discovered traces of an ancient beach, composed of rounded fragments of red and white chalk, immediately reposing upon the greensand, and covered by 9½ feet of sandy loam containing small angular fragments of flint." He observed, too, that "it rises toward the east from Lynn Bay, consequently it inclines in an opposite direction to the regular strata." †

In 1883, when the cliff gardens were being laid out, an excellent section of these beds was exposed, and was seen by MESSRS. CAMERON and JUKES-BROWNE. The following notes are by the latter :—Just above the newly-excavated pond the cliff showed the section represented in Fig. 8.

Figure 8. Section in the Cliff Gardens, Hunstanton. (JUKES-BROWNE.)

e. Surface Wash. *c*. Boulder Clay. *a*. Carstone.
d. Sand. *b*. Gravelly layer.

Length of ground represented = 35 to 40 yards.



The measurements in the centre of this hollow were :—

	Feet.
Gravelly soil and wash	2
Clean sand and hard loamy brown sand	8
Brown Boulder Clay, gravelly at base	8
Carstone, exposed for	6

At one point the sand and boulder clay were dovetailed into one another, and a little south of this point a lenticular bed of sand occurred in the boulder clay, having a maximum thickness of 2 feet. At the southern end of this section the depth of the Drift was only 10 feet. The clay contains angular fragments of basalt, porphyrite, and other igneous rocks, but not much chalk.

To the south of the place where the above section was seen the Boulder Clay deepens again and descends to the level of the beach, becoming at the same time more purple in colour.

A small tract of sand and gravel extends from a little north of Hunstanton Station southward for about half a mile, and the beds are exposed in two pits near the gasworks. MR. CAMERON describes them as consisting of stratified and false-bedded sand and gravel, composed partly of flint *débris* and quartz sand, with many pebbles of sandstone and of igneous rocks, and streaks of coaly matter.

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* *Phil. Mag.*, 3rd ser., vol. viii., p. 34.

† MR. ROSE speaks of the deposit as an ancient beach, but it must not be confounded with the marine gravel near the gasworks, which is generally known as the "raised beach" (see p. 90).

PROF. H. G. SEELEY gave a good description of this deposit as seen in 1866, from which we quote the following account :—"South of the railway-station a hill has been cut into for ballast, exhibiting ash-coloured sands and gravels 30 feet thick without reaching the bottom. The cross stratification is very marked, and the beds differ much in different parts of the pit. In some of the bands the pebbles were almost as well rounded as on a pebble shore like Dunwich. Shells occur in several distinct bands of gravel, and at various heights, but are most numerous and best preserved in the coarse layers.

"This deposit is remarkable for the absence of local fragments (the Red Chalk occurs but rarely and then only in small pieces which may have come from the north); for the included fragments comprise every kind of rock, numerous granites, syenites, traps, Cambrian, Carboniferous, Lias, Middle Oolites, Kimeridge Clay, Shanklin Sands [Carstone], Speeton Clay, chalk and flint, and lignite, and these in such proportion that it can hardly be called a flint-gravel. Besides these are numerous balls, rough and round, formed of pieces of clay which had rolled on a shore and so acquired a coating of pebbles. At the top is an earthy gravel with *Ostrea edulis*, *Mytilus edulis*, *Cardium edule*, &c., very recent, for the Mytilus still preserved its epidermis. The large shells were broken and all showed marks of drifting in breakage, wear or separation of the valves."*

PROF. SEELEY gave a list of 12 species of Mollusca which he had obtained from these beds, and MR. SKERTCHLY, in his Fenland Memoir (p. 202), gave a list of 16 species identified by MR. F. W. HARMER from specimens in his own collection, but four of those mentioned by PROF. SEELEY do not appear in MR. HARMER'S list.

The following list has been drawn up by MR. G. SHARMAN from that of MR. HARMER, with some additions from specimens in the Museum at Jermyn Street.

Buccinum undatum, *Linn.*
Dentalium entalis, *Linn.*
Littorina littorea, *Linn.*
Murex erinaceus, *Linn.*
Nassa nitida, *Jeff.*
„ reticulata, *Linn.*
Natica (fragment).
Purpura lapillus, *Linn.*
Turritella communis, *Risso.*
Artemis lincta, *Pult.*
Cardium edule, *Linn.*
Corbula gibba, *Olivi.*
Cyprina islandica, *Linn.*
Donax vittatus, *Da Costa.*
Mactra ovalis, *J. Sow.* (= M. elliptica).
Mytilus edulis, *Linn.*
Nucula nucleus, *Linn.*
Ostrea edulis, *Linn.*
Scrobicularia piperata, *Gmel.*
Tapes pullastra, *Mont.*
Tellina balthica, *Linn.*

With respect to the age of this marine deposit it has been considered both by PROF. SEELEY and by MR. SKERTCHLY to be of the same age as the gravels at March and Whittlesey in the Fenland and at least 14 species out of the preceding list of 20 species occur in the March gravel. Moreover, its elevation above the sea is about the same as that of the March gravel, *i.e.*, 20 to 30 feet.†

Now the March and Whittlesey gravels occur on islands in the Fenland, and are certainly older than the clays and silts of the Fenland, moreover they contain the extinct species *Cyrena fluminalis*, and for this reason they have been correlated by MR. SEARLES WOOD, Jun., with the gravel of Kelsea Hill in Yorkshire. MR. WOOD, indeed, in 1882, definitely expressed the opinion that the Hunstanton gravel was of the same age as that of Kelsea Hill, in spite of the non-occurrence of the *Cyrena* at the former place.‡ But the Kelsea Hill deposit is distinctly overlain by the Hessle Boulder Clay, and is therefore regarded by the Geological Survey as a Glacial Gravel.

It is therefore a question whether the Hunstanton gravel is not of the same age as the Brown Boulder Clay which adjoins it. So long ago as 1879 I ventured to suggest that this gravel might possibly be of the same age as the Hessle Beds,§ and as I now feel sure that Hessle Clay occurs at Hunstanton

* *Quart. Journ. Geol. Soc.*, vol. xxii.
† See Explanation of Sheet 65, Mem. Geol. Survey.
‡ *Quart. Journ. Geol. Soc.*, vol. xxxviii., p. 698.
§ *Quart. Journ. Geol. Soc.*, vol. xxxv., p. 415.

this suggestion acquires more weight. No evidence to connect them, however, was found by those of my colleagues who surveyed the ground, and it was then thought safer to colour it on the map as a Post-Glacial Deposit.

It should be mentioned that MR. B. B. WOODWARD wrote a "Note on the Drift Deposits of Hunstanton" in 1883,* in which he describes both the Glacial Drift in the cliff and the marine gravel near the gasworks. He found from a hole dug in the floor of the pit that the gravel at the latter place rests on a bed of chalk-rubble; a fact which was subsequently noted by MR. H. B. WOODWARD, who describes it as "a bed of chalk *débris* and broken flints which had much the appearance of Chalky Boulder Clay."

MR. LAMPLUGH has recently had an opportunity to re-examine this pit (June, 1898), and reports some important changes in the section, the Carstone having been reached at its eastern face and excavated to a depth of 3 or 4 feet. He supplies the following section of this part of the pit:—

	Feet.
Top soil, passing into—	
Sandy loam with scattered small pebbles of Flint, &c., not arranged in layers; probably rain-wash ...	3 to 5 (sometimes thicker in other parts of the pit).
Clean-washed fine gravel with worn shells; sand with small particles of shell below...	0 to 5
Irregular streaks of red-brown clay, swelling in places into a band 2 to 3 feet thick, and then containing scattered stones like a boulder clay. This rests on the flanks of a dome of the sands below, and passes into them in places	0 to 3
Fine palish buff sand, with loamy layers, with cross-bedding in part parallel to the dome-like upper surface	3 to 10
Fine sandy damp loam, with an irregular streak of red clay containing a few small fragments of chalk	3
Rusty sand made up of Carstone *débris*, with gravelly layers of subangular fragments of red and white chalk	2 to 3
Wedges of hard clayey chalk-rubble, made up of angular and subangular pieces of chalk and flint, with an occasional small pebble probably derived from the Carstone: resting on, and in part wedged into, the upper surface of the Carstone	0 to 2½
Carstone: firm chocolate-brown coarse sand ...	3½

MR. LAMPLUGH remarks that, although the beds are extremely variable in different parts of the pit, the red-brown clay could be traced in most of the sections, the shelly gravels occurring below as well as above it. A seam of bouldery "cannon-shot" gravel, with stones a foot or more in diameter, was exposed at the southern end of the pit, where the Carstone was not reached. Flints were by far the commonest stones, but there were also lumps of hard White Chalk bored by *Cliona* and *Saxicava*, Red Chalk, Carstone concretions, fossiliferous pebbly (Spilsby) Sandstone, large calcareous nodules (probably Kimeridge) bored by Cliona, a well-striated boulder, 8 in. × 5 in. × 5 in. of reddish gritty (carboniferous?) limestone, and a few other far-travelled blocks of Basalt, Gneiss, &c.

He concurs in the above-expressed opinion that the gravel is not Post-Glacial, but is of the same age as the Brown Boulder Clay of the adjacent coast-section, and of similar date and origin to the shelly gravels of Holderness.

From information obtained at the pit it appears that the human skeleton recently found in it† lay at the base of the sandy loam, at the top of the gravels.

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* *Proc. Geol. Assoc.*, vol. viii., p. 97 (1885).

† See T. E. Newton, *Proc. Geol. Assoc.*, vol. xv., p. 258 (1898).

What is probably a continuation of the bordering strip of reddish Boulder Clay sets in again south of Hunstanton, running southward by Heacham Railway Station and along the border of the marsh west of Snettisham; it terminates in a ridge or bank which juts out into this marsh by Shepherd Port. The railway-cuttings north of Snettisham Lodge are cut through this clay, but the only note of its colour or character that has come into our hands is one by MR. WHITAKER, in which he remarks that the pinkish-brown loam or Boulder Clay comes on above the Lower Greensand in the cutting N.E. of the Lodge.

Reddish and purplish Boulder Clay of the Hessle type occurs again in the north-western corner of the district, rising up from beneath the Fen deposits and forming two broad isolated banks or islands on which are situated the villages of Sibsey and Stickney. These banks are probably the higher parts of a ridge which passes southward beneath the Fenland toward Boston, and there seem to be traces of the same clay in the mottled brownish Boulder Clay which was exposed in making the Docks at Boston in 1882-1884.

The following section was seen in the dock excavations in 1883, the account being taken from MR. JUKES-BROWNE'S paper on the Boulder Clays of Lincolnshire* :—

Clay and silt	18 feet.
Peat	1 foot.
White and grey sands	1 „
Reddish sand and gravel lying in pockets of the clay below	6 feet.
Mottled buff and grey Boulder Clay ...	

In a deeper trench between the dock and the river a dark blue Boulder Clay was exposed underneath the mottled clay which forms the base of the dock section. The line of junction was not clear, but appeared to be sharp.

The following note by MR. WHITAKER confirms the above so far as concerns the colour of the clay below the alluvial deposits :—

In January, 1882, I visited the works of the new Witham Outfall, at the edge of The Wash below Boston. The long cutting showed Alluvium (silt) from 10 to 15 feet thick, over Boulder Clay, the junction being even and horizontal where seen; but MR. W. H. WHEELER, who kindly showed me the section, says that it sinks slightly seaward, when the Boulder Clay is not touched so soon. This clay was bluish-grey, mottled brown, firm and dry; only a few large stones have been found (up to 2 or 3 feet in length) and no very large ones. We saw at one spot a little bright green sand, derived from a Cretaceous bed, and many small nests of sand in the clay. I was told that sometimes a little sand and gravel has been found between the silt and the clay. W. W.

Gravels of Uncertain Origin.

1. *Brancaster and Burnham.*—A tract of sand and gravel overlying but possibly connected with the Brown Boulder Clay, occurs at Brancaster, and a still longer tract of similar material underlies Brancaster Staith and Burnham Deepdale. These patches have also been coloured as Post-Glacial Gravels on the map, and no evidence was obtained by the Surveyors as to whether they were marine, estuarine, or freshwater deposits.

The only note regarding them which has come into our hands is one by MR. CAMERON to the following effect :—A belt of sand and gravel, but principally sand, and of considerable thickness, borders the chalk-land overlooking the Brancaster and Burnham Marshes.

This gravel seems to extend into the valley which descends from Hawker's Hill, and in which there is also gravel, loam, and Boulder Clay belonging to the Brown Clay group (see p. 87).

Wootton.—The tract which borders the marshland by North and South Wootton may be marine gravel and sand comparable with that at Hunstanton; but as there are other tracts in a similar position farther south (in Sheet 65), and these have been regarded as River Gravel, a note referring to this patch will be found under the head of Valley Gravel (see p. 94).

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* *Quart. Journ. Geol. Soc.*, vol. xli., p. 122.

CHAPTER 9. VALLEY GRAVELS.

The streams which flow off the higher ground in the south-eastern part of the area under description are bordered here and there by strips of valley gravel ; and some of the valleys which are not occupied by permanent watercourses also contain deposits of sand and gravel washed into them during times of heavy rainfall.

Congham and Roydon Valley.—A narrow strip of gravelly wash occupies the bottom of this depression near the southern edge of the map west of Great Massingham. MR. WHITAKER found a pit in this a little eastward of Congham Common and about three miles west of Great Massingham Church ; he observed that this showed a sort of chalk-wash to a depth of 12 feet or more, mostly in the form of fine calcareous sand or sandy marl, which in parts contained broken shells of *Bythinia tentaculata* with loose opercula of that Mollusc. The top part contained flints on the northern side (by the roadway), and on the southern side was covered with sand washed down from the ridge of Glacial Sand which almost reaches to the pit.

Part of Roydon, near Grimston Road Station, is underlain by sand and gravel, forming part of a tract which passes south-west into the area of Sheet 65.

Massingham and Babingley Valley.—The upper part of this valley is usually dry, but the lower part is occupied by a stream which rises from springs near Flitcham. MR. WHITAKER furnishes the following notes on deposits in this valley :—

A pit south of the railway, about a quarter of a mile west of Massingham Station, showed pale grey (almost white) marl, with lumps of Chalk in the bottom part, and with broken land and freshwater shells, the opercula of *Bythinia* being alone distinguishable. At the eastern side of the entrance rubbly chalk was seen to rise up to the height of two feet. The rest of the marl is not stony, but the bed contained an unctuous black peaty layer, from three to six inches thick, which rose up irregularly north-westward, but on the southern and highest side was nearly flat and some three feet from the bottom : this layer seemed to thin eastward, where the very bottom of the marl is of a darker grey (? from wet) and partly sandy. The marl was seen to a depth of 10 feet, the top being hidden by soil, and it showed traces of bedding. It has been dug to manure fields, and is clearly a Post-Glacial deposit.

The northern side of the western end of the wee cutting on the railway seems to be in like marl, and a small old pit farther west (on the south of the railway about two thirds of a mile from the station) seems to show a little of the marl underlain by whitish Boulder Clay, the two being alike in tint. This pit is in a slight fall of the ground. A deeper old pit on the rise just west may also be in marl, judging from the growth of trees and of bushes.

An old pit near the bottom of the valley, more than $1\frac{3}{4}$ miles W.N.W. of Little Massingham Church, gave the following section :—

Brown clay and loam, with some flints, irregularly piped over the underlying, of the decalcification of which it is clearly the result to a great extent.

Whitish and buff fine sandy marl and loam, with some small pieces of shell and opercula of *Bythinia* up to 10 feet seen.

Near Hillington the valley opens out, and tracts of gravel come in on each side of the stream. One of these stretches from near Hillington Hall to within a mile of Castle Rising.

A large gravel-pit in a field, rather over a mile west of Hillington Station, was only open in part in 1881, to a depth of nearly 12 feet. The gravel here is chiefly composed of small pebbles of hard chalk; it is mostly stained yellow, but in the upper part is whiter and more chalky-looking.

An old pit just south (almost touching) was overgrown; it had water in the bottom, and some similar gravel was to be seen.

Babingley Farm stands on another tract of similar gravel, which is surrounded on three sides by alluvium. W. W.

South of the entrance to the Babingley River a strip or terrace of gravel and sand runs southward along the border of the marshland by North and South Wootton. In the absence of evidence to the contrary this has been coloured as river-gravel on the map, and it is, therefore, mentioned in the present connection, though it may possibly be of marine origin, like the sands and gravels which occur at about the same level elsewhere on the borders of the Fenland. Most of it appears to be from 25 to 40 feet above the sea-level. It rests partly on Boulder Clay and partly on Lower Greensand and Kimeridge Clay. No good exposures were noticed, but the following note on one part of it is communicated by MR. WHITAKER :—

Just north of the road to Castle Rising, nearly two thirds of a mile E.N.E. of North Wootton Church, are old pits and ponds, showing beds that I could not make out with any certainty. At one point, between two ponds, there is sand up to nearly four feet thick, partly gravelly and underlain by messy gravel, with bits of fissile clay and some peaty clay (? Kimeridge), and partly itself clayey, with some pieces of sandy iron-ore (? from Lower Greensand), and up to nearly three feet thick. Near the road (and south of pond) there is some grey and brownish sandy clay.

I had originally mapped Boulder Clay here, but perhaps these beds would be better classed with the clay or brick-earth, of which there is some sign hereabouts. Can there be any of the clayey division of the Lower Greensand? W. W.

Wensum Valley.—In the south-eastern corner of the area are three rivulets which form the head waters of the Wensum. The southernmost of these commences at Lowe Farm, but its valley is continued westward into Kipton Heath, and a narrow strip of gravelly wash has been mapped along this portion of it. MR. WOODWARD remarks, however, that it is not easy to separate it from the older accumulation, though in places it is thick enough to be worth working for gravel.

The following notes are also by MR. WOODWARD :—The stream running through Rudham is bordered by a shallow deposit of gravel lying on the Chalk, and the latter is much disintegrated and stained in places.

Creake and Burnham Valley.—In the dry valley coming from the west to North Creake there is a deposit of sand and gravel which has been washed down the slopes. From North Creake to Burnham Thorpe another tract of sand and sandy gravel extends along the western border of the Alluvium. In a sand-pit opposite Creake Abbey MR. WOODWARD saw about 10 feet of fine calcareous sand, which he was disposed to regard as of Glacial age, till the mapping appeared to connect it with undoubted Valley Gravel in a northerly direction.

Burnham Westgate stands on gravel which has evidently been brought down the valley, which comes from the south-west. From Burnham Ulph gravel borders the Alluvium of the main valley as far as the north end of Norton Street. H. B. W.

Ringstead Valley.—Passing to the north-western corner of the Chalk area, the dry valley, which begins near Thornham Ling and runs by Ringstead St. Peter, has a flooring of sand and gravel which extends for a distance of more than two miles. As in so many other cases this is a deposit washed from the neighbouring slopes by rain-floods into a valley where no permanent stream exists to carry it onward to the sea.

A. J. J.-B.

CHAPTER 10. THE FENLAND AND ALLUVIAL DEPOSITS.

1. The Deposits of the Fenland.

All the eastern and south-eastern portions of the area included in Sheet 69 belong to the Fenlands of Lincolnshire. The whole area of the Fenland has been dealt with in a separate Memoir,* but it is desirable to quote such portions of it as relate to the districts now under description.

Before the publication of Mr. Skertchly's work the general opinion regarding the deposits of the Fenland was that they were chiefly of freshwater and estuarine origin, and that the clays and peats of this series passed seaward beneath a marine silt which was quite distinct from the "Buttery Clay" of the Cambridgeshire Fens. Mr. Skertchly proved that this was a mistake, that on the contrary the mass of the Fen deposits is of marine origin, the Buttery Clay being as much marine as the silt; neither did he find that there was any definite order in the succession of the beds of clay, silt, and peat.

The substratum of the deposits in the northern part of the Fenland is either Boulder Clay, or Kimeridge Clay, or Oxford Clay, and the surface of these clays is very uneven, so that the depth of the Fenland deposits varies very much. Generally speaking, however, it is greatest near the sea-bord, where the beds are often about 40 feet deep.

The lowest bed or bottom deposit is generally a sand or sandy gravel which often contains marine shells; sometimes, however, there is no sand or gravel, and then peat or clay rests directly on the older formation. Dark-coloured clays and silts are the principal components of the Fenland deposits, but interbedded with these are beds of peat, sometimes two or three such beds occurring one above another with intervening beds of clay. In some places peat has been the last surface-growth, but over the greater part of the area entering into this Sheet (69) marine silt has been the latest deposit and forms the surface soil.

Just as The Wash is not an estuary, but a bay, so the Fenland must be regarded as a silted-up bay or arm of the sea, the deposits beneath it being essentially marine with only local intercalations of freshwater beds and terrestrial growths.

The Clays and Silts.

These vary in character and colour; some beds consist of a fine sticky or "buttery" clay, generally dark blue or grey, but there is every gradation from a clay to a fine silt or sandy warp, such as is deposited by spring tides on the shores of The Wash at the present time.

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* "The Geology of the Fenland," by S. B. J. Skertchly., *Mem. Geol. Survey*, 1877.

MR. SKERTCHLY writes: This warp is an exceedingly fine sandy deposit of a light reddish-brown colour, lying in fine laminæ which sparkle in the sun with fragments of mica and comminuted shell. It is not so widely spread as the clay, but forms most of the surface of the ground in the neighbourhood of the sea, fills up old creeks, forms little hillocks, and extends far inland in some places. . . . The warp gives to the surface of the ground a ruddy tint, very different from the coaly peat surface, and it is not unusual to hear of "red fen" and "black fen." It is very full of Foraminifera, hardly a square inch being destitute of their remains.

The Fen Clays are generally dark blue or purplish-brown, and are sometimes mottled blue and brown. When wet they have a glistening, unctuous aspect. The blue clay often passes into silty clay, and is always what the brickmakers call a "light" clay, as distinguished from the "strong" Oxford or Kimeridge Clays. Of these clays MR. SKERTCHLY says: They often contain carbonaceous markings and fragments of wood, and occasionally drifted trunks of sallow and willow. When wood is plentiful the bright blue phosphate of iron (*Vivianite*) occurs in amorphous earthy lumps and streaks, varying in size from fine specks to bits as large as a bean.

Of the marine shells occurring in the clays and silts the commonest is *Scrobicularia piperata*, many as single valves, but some with both valves in natural position. A few shells of *Tellina balthica* occur, and in places dwarfed specimens of *Cardium edule*, *Mytilus edulis*, and *Ostrea edulis*. In some few places little *Rissoæ* are plentiful. Here and there a few bones of ox, pig, whale, seal, and grampus are exhumed, but very sparingly. S. B. J. S.

The following are sections in brickyards seen and recorded by MR. SKERTCHLY in the Memoir already quoted. They serve to illustrate the variations that occur in the beds which compose the deposits of the Fenland:—

Cow Bridge Brickyard, north of Boston.

Clay	4 feet.
Silty clay	3 „
Blue clay	6 „
Peat resting on sand...	0½ foot.
	13½ feet.

Baptist Cemetery Lane, Boston.

Blue clay	11 feet.
Peat	1 foot.
Gravel and sand	3 feet.
Boulder Clay at base...	—
	15 feet.

High Bridge Drain, near Boston (or Boston East Brickyard). On the east side the succession was as follows.

Silt	13 feet.
Peat with tree roots	1 to ½ foot.
Sand and gravel...	6 inches to 6 feet.
Boulder Clay (a white sandy clay with chalk-stones)	
	Up to 20 feet.

On the western side the silt was entirely replaced by clay. The sand and gravel evidently lay on a very uneven surface of Boulder Clay, compare the section seen at the Boston Docks (p. 92).

MR. W. H. WHEELER, of Boston, writing on the borings and excavations made for the Boston Docks, says: "The brown clay which lies below the alluvial soil is a good brick-clay. The blue clay under this is a soft buttery clay full of peaty matter or old rushes; it burns very badly, the peat burning away leaving the ballast light. This (blue) clay is full of beds of shells (cockles, mussels, &c.) quite perfect, and is in as good preservation as if found in one of the creeks on the marshes at the present day.

"In the peat which usually runs from nine inches to a foot thick are the remains of trees, some only stumps, others trunks lying on their sides. They appear to be oak, poplar, and birch, and there is a great deal of birch bark, bright and silvery as if just off the trees. The oak is black and as bright as ebony."

Wyberton Chain Bridge, Boston.

Silt, setting in and replacing clay ...	0 to 3 feet.
Clay, thinning from	11 to 8 „
Peat	8 inches.
Sand and gravel	2½ to 3 feet.
Boulder Clay, dug into for	3 „
	About 17 feet.

Kirton Road Brickyard, in Wyberton Parish, between Boston and Kirton.

Silt	4 feet.
Clay	11 „
Peat	3 inches to 1½ foot.
Clay and gravel mixed	1 „
Boulder Clay below	—
	About 17 feet.

MR. SKERTCHLY states that the peat is sometimes wanting, and its place taken by a bed of sand 1 foot 6 inches thick. He also gives a section taken 200 yards south of the above which showed :—

	Feet.
Soil and Silt	3
Clay, turfy below	11
Peat	1
Sand, not pierced, dug to	3
	18

A brickyard at Fleet Low Gate, near Holbeach, showed 8 feet of silt and clay on the east side, and 16 feet on the west side, the substratum throughout being described [? by the workmen] as "sea-sand." Other sections and wells near Holbeach and Gedney show from 5 to 7 feet of silt and clay, with fine sand or sandy silt below, sometimes containing cockle-shells (SKERTCHLY, pp. 276, 277).

The Peat Beds.

Beds of peat occur at so many levels in the mass of Fenland clays and silts, that is to say, they vary so much in number and in depth from the surface in different places as to make it improbable that any one of them is continuous over the whole area, or even over any large part of it. Sections may be seen along the banks of some of the waterways, which show peat beds

setting in at various horizons and thinning out again, sometimes in very short distances. Borings and wells have proved the existence sometimes of three or four separate layers of peat, while in others not far away only one bed was found.

These and other facts convinced MR. SKERTCHLY :—

1. That throughout the whole "Fen Period" the climate was favourable to the growth of peat which formed whenever the sea had no access to a given area.
2. That the alternations between marine and freshwater conditions were very variable, being in some areas frequent, and in others but seldom ; and consequently that no classification, such as Upper Peat, Buttery Clay, and Lower Peat can hold good.

The thickness of the subterranean peat beds also varies greatly, from a few inches up to 10 or 12 feet. Some of the peat beds contain trunks of trees, and when these are numerous such beds have been called "buried forests." MR. SKERTCHLY observes that peat with trees is of more frequent occurrence near the borders of the Fenland, or round islands in the Fen, as if the forests of the adjacent higher lands had at certain periods of desiccation spread outward over the borders of the Fens.

"Buried forests" have been found at two localities within the area of Sheet 69 ; (1) in East Fen, near Stickney, in the north-western part of the area ; (2) on the foreshore north-west of Old Hunstanton and Holme.

The trees found in these beds are principally oaks, but elm, birch, yew, willow, and sallow also occur. The roots are frequently to be seen buried in the bed which underlies the peat. Most of the trees are mere trunks, broken off at the bole and at the fork. "The oaks are in all cases stained black ; the yews retain their peculiar brown colour, and the timber of the firs is as white and sound as if from living trees, the odour of turpentine being distinctly perceptible in cutting the wood."

MR. SKERTCHLY also found that the lie of the tree trunks is almost always in one direction, namely, south-west and north-east, their heads being directed to the north-east. The following is a quotation from MR. SKERTCHLY'S Memoir (p. 162) :—

The direction of the trees in the Fenland agrees with that observed in the mosses of England and Scotland, and, as was first pointed out by RENNIE in 1807, this is the direction of the prevailing winds. "If," says he, "in any moss they (the trees) lie in one direction, the probability is that they have been overset by the wind." This opinion has been endorsed by nearly all succeeding authors, and it is true in regard to the buried forests of the Fenland.

Many of the dykes and droves are bordered by fine-grown aspens, and they slope towards the north-east. When a long line of these slender trees is seen thus bowed in one direction, the appearance is very striking. This north-easterly trend is

towards the sea, but on the coast itself the sea breezes exercise their influence, and the trees all bend away from the water, as may be seen to perfection at Hunstanton. In Fig. 9 a group of trees sloping in the usual direction is represented; it was sketched in the neighbourhood of Holbeach.

S. B. J. S.

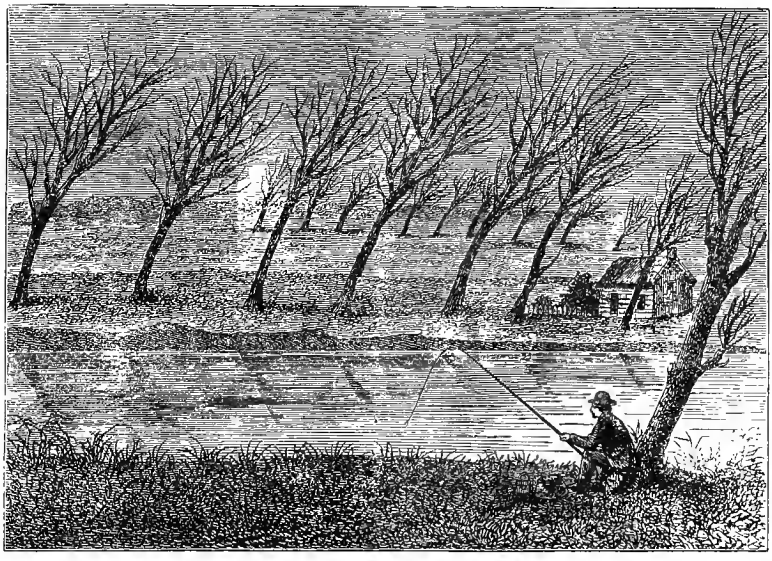

Figure 9.—Trees near Holbeach. (SKERTCHLY.)

From SKERTCHLY'S "Geology of the Fenland," p. 162.

The only district in this part of the Fenland where peat forms the surface soil at the present time is that known as East Fen on the northern border of the map. Only a portion of the peat-covered area comes within this sheet, the rest lying within the limits of Sheet 84. Up to the beginning of this century this fen was unenclosed, and Gough in his edition of Camden's Britannia (1789) remarks of East Fen that "it is quite in a state of nature and exhibits a specimen of what the country was before the introduction of draining. It is a vast tract of morass, intermixed with numbers of lakes, from half a mile to two or three miles in circuit, communicating with each other by narrow reedy straits. They are very shallow, none above four or five feet deep, but abound with pike, perch, ruffs, bream, tench, dace, eels, &c."

Mr. SKERTCHLY gives the average thickness of the peat in East Fen as six feet (Table, p. 156), but says it varies in depth, "being always under 10 feet and often less than three feet."

The abstraction of water in the process of drainage caused the peat to shrink and the surface to sink two feet between the years 1806 and 1866.

2. The Marshlands of Norfolk.

The marshes which border the land on the eastern side of The Wash are of the same character as the Fenland itself, and consist mainly of sediment deposited by the waves of The Wash at high tide. This marine alluvium has a very irregular border on the land side, filling up the lower ends of its valleys and depressions.

There is a brickyard half a mile north of Castle Rising where the clay of the alluvial level is burnt into bricks. It is probably to this clay that the Rev. G. B. Moxon refers in the following passage:—"At Castle Rising in the Valley of the Ouse, the brick-earth is five feet thick upon turf 18 inches deep; underneath this is a bed of shingle."*

The following note by Mr. Whitaker relates to the soil of the inlet between Wolferton and Dersingham Common:—In 1882 a freshly-cut ditch near and roughly parallel to the railway, some way northward of the seven-mile post and about three quarters of a mile E.N.E. of Wolferton Station, showed thin clayey or loamy alluvium over sand, the former sometimes thickening suddenly and filling hollows in the latter. Many bits of flint were turned out, so that some, if not all, of the sand is either a bed belonging to the alluvium or a Valley Drift.

From a point opposite Dersingham Common northward to the commencement of Hunstanton Cliff the marshland is bordered on the seaward side by a bank of shingle.

With respect to the tract of marshland which borders the northern coast of Norfolk, the present writer thinks that it has been formed in the same way as that just described along the western coast, and as that along the eastern coast of Lincolnshire. It is, in fact, a miniature counterpart of the Lincolnshire Marshland, for the Alluvium rests on and against the low-lying brown Boulder Clay, and it is protected on the seaward side by a line of sand-dunes or hills formed of blown sea-sand (see Fig. 7, p. 88). There is another point of resemblance which links it both to the Lincolnshire Marshland and to the Fenland; this is the existence of a buried forest or layer of peat and trees, which underlies the surface clay and crops out on the foreshore at about low-water level in places between Hunstanton and Brancaster.

Mr. H. B. Woodward† has suggested that this marshland is part of an old river valley, the northern border of which has been destroyed by the sea, but there is no evidence for this view beyond the fact that the tract in question looks like one side of a valley filled with alluvium. It was natural that such an idea should occur to one who had been surveying parts of East Norfolk, but to anyone familiar with the marshlands

* *Proc. Sci. Soc. Lond.*, vol. ii., p. 64 (1840).
† "Geology of Fakenham, Wells, and Holt," *Mem. Geol. Survey*, p. 44.

round The Wash it seems equally natural to regard it as a tract of marine alluvium, and this view has the advantage of not requiring the hypothesis of high land to the north of the existence of which no tradition exists. Moreover, if the Alluvium had belonged to a valley descending from east to west, or *vice-versa*, this Alluvium would not keep at the same level.

The existence of the ancient forest-bed has been known for a long time, and it has been described by several writers, but it is only accessible by boat at times of the low spring-tides. The following description of it is by the REV. G. MUMFORD* :—

"This now submerged tract was once inhabited by herds of deer and oxen, as is evident [?] . . . from the remains of their horns and bones which have occasionally been found there. The foot of man has also trodden these now ruined wastes, for works of art have been met with buried, with the forest, beneath the waves. It is difficult to reach this overwhelmed forest from Hunstanton without the assistance of a boat. . . . About two miles north of the cliff, and a mile and a half from high-water mark, we arrived at the prostrate forest, consisting of numberless large timber trees, trunks, and branches, many of them decomposed, and so soft that they might easily be penetrated by a spade. These . . . lie in a black mass of vegetable matter, which seems to be composed of the smaller branches, leaves, and plants of undergrowth, occupying altogether a space of 500 or 600 acres. Many of these trees, however, are quite sound, and . . . are sometimes used . . . for posts and rails. But the most extraordinary thing we met with in this expedition [1831] to the submarine forest was a British flint celt or axe embedded in the trunk of one of the decomposed trees, above an inch and a half of its cutting edge."

MR. GUNN mentioned at a meeting of the Norwich Geological Society on November 21, 1871, that he had found remains of the Fallow Deer in this submerged forest at Hunstanton.

MR. REID saw part of a similar submerged forest exposed at low-water of spring-tides in Brancaster Bay (see p. 87).

It is not likely that the submerged forest beds of Norfolk and Lincolnshire were ever continuous across The Wash, as MR. MUMFORD imagined when writing his account, although they closely correspond in level, in character, and in contents. They probably represent temporary and local extensions of a terrestrial surface across the Marshland Plain, and were formed in precisely the same way as the "buried forests" of the Fenland, the formation and local characters of which have been discussed by MR. SKERTCHLY (see also p. 98).

A glance at the Geological Survey map and the position of the submerged forest-bed north of Hunstanton will show that the northern Marshland must once have extended considerably farther westward, and was then in all probability continuous with the marsh which lies behind the shingle south of Hunstanton. Hunstanton Cliff is the only place along this part of the coast-line where the sea has eaten into the land which lies behind the belt of marshland. It would seem that some change

* "Sandringham: Past and Present." By MRS. HERBERT JONES. With some Historic Memorials of the Norfolk Coast. 8vo, *London*, 1883, pp. 193-195.

occurred in the set of the currents, and that the north-western corner of the Marshland has been eaten away, as well as the Boulder Clay low-land which lay at its back, so that the sea now infringes upon the Chalk high-land which once overlooked the lower ground, both to the north and west.

Blown Sand.*

The coast-line from Gibraltar Point, E.S.E. of Wainfleet, and northwards n Lincolnshire, is bordered by hillocks of Blown Sand. Again, along the Norfolk coast, from Hunstanton to Burnham Harbour, the marshes are fringed on the sea-margin by long lines of sand-dunes, accompanied at Holme Scalp by shingle.

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* See also Jukes-Browne, "Memoir on Geology of East Lincolnshire," p. 111; and H. B. Woodward, "Geology of Fakenham, Wells, and Holt," p. 43.

CHAPTER II. THE WASH: ITS PHYSICAL GEOGRAPHY, AND HOW IT IS SILTED UP.

It has been stated in the preceding chapter that the area now occupied by the Fenland was once an arm of the sea, and that, with the exception of the intercalated beds of peat, the Fenland deposits are of marine origin, their materials having been brought in from the sea, and having taken the place of so much sea-water.

The Wash is the only remaining portion of this great bay, and the process of silting up has been going on up to the present day, so that continual additions have been made to the Fenland, and it can be shown that in some places a breadth of three miles of land has accreted since the Roman occupation.

It is evident, therefore, that in order to understand how the great expanse of the Fenland has been formed, it is necessary to study its present shores and inlets, and to watch the process of deposition which is now going on. This was done by MR. SKERTCHLY, and the remainder of this chapter is entirely taken from his Memoir on the Fenland; two of his chapters have been laid under contribution, some small corrections made, and some tables omitted in order to make the whole more compact and readable.

THE WASH.

The Wash is the great bay into which the fen-rivers flow. It is the *Metaris Æstuarium* of the Romans; and, perhaps for no other reason, it is still called an estuary. It is, however, no more the estuary of the fen-rivers than the German Ocean is the estuary of the Ouse or of the Thames. An estuary is the seaward continuation of a river-channel, a breach of the coast from the land-side. A bay is an indentation of the land, a breach of the coast from the sea-side. The Wash is of the latter character, that is, a true bay and not an estuary. The estuaries of the fen-rivers are now enclosed marshes; and The Wash, whatever parts of its area may formerly have been, holds no such relation to the rivers, nor are any of the fen-beds delta-deposits.

The width of the mouth of The Wash from Hunstanton Light to Gibraltar Point is 12 miles; the length, from the centre of a line joining the above points to Fleet Haven, is 14·8 miles; the greatest length, from Hunstanton Light to Fosdyke Bridge, is 23 miles; the greatest breadth, from near South Wootton to the Witham outfall, is 18 miles, and the area is 250 square miles, measured within the line drawn from Hunstanton Lighthouse to Gibraltar Point.

The configuration of The Wash is peculiar. Roughly speaking it is a shallow bay with an average depth of, say, five fathoms, but having a deep hollow (Lynn Well) in the centre, ranging from 15 to 26 fathoms. The

eastern and western shores are fringed with sands, sloping very gently seaward from high-water mark. The base (that portion lying between the Ouse and Welland outfalls) is blocked with immense accumulations of sand, broken by shallow channels and sending out spurs in a north-easterly direction.

In describing The Wash, however, we must include much more than The Wash proper as above defined. On the east a great shoal, called Burnham Flats to the south, and Docking Shoal to the north, extends about 12 miles north of the Norfolk coast. On the west a less perceptible shoal, broken by Boston Deep, extends beyond Boston Bar and Long Sand. At the base this shoal still continues and joins that first mentioned. The great shoal we have described in three sections is bounded seaward by the five-fathom line, and averages perhaps two fathoms in depth. Parts of it are dry at low water; such are the following, the figures referring to feet below low-water springs :—

The Woolpack	1	Hook Hill	2 to 8
Middle Bank	5	Herring Sand	4 to 10
Sunk Sand	5	Mare Tail	2 to 8
Doghead Sand	6	Westmark Knock ...	7 to 10
Outer Knock	5 to 9	Whiting Sand	5
Long Sand	3 to 8	Thief Sand	8
Roger Sand	2 to 11	Seals Sand	6 to 11

The above sands are unconnected with the shore, the following directly join it :—

Stubborn Sand	8	Beaumaris Sand ...	7 to 14
Ferrier, Bulldog, and Vinegar Middle Sands	1 to 14	Middle Bank	8
		Breast Sand	8
Daseley's or Pandora Sand	3 to 11	Hull Sand	9 to 11
		Cat Sand...	6 to 11

Between Long and Roger Sands and the flats outside the coast is the channel known as Boston Deeps (a term, I believe, used only in The Wash), at the entrance to which is a bar having only $1\frac{1}{8}$ fathoms of water at Low-water springs. Inside the bar the soundings are $4\frac{1}{2}$, 5, 6, 7, 6, 5, and $4\frac{1}{2}$ fathoms as far south as Clayhole, where the water shoals again to 1 fathom. Boston Deep is therefore a basin whose lip is 1 fathom below the Admiralty datum; but it is merely a score out of the great shoal.

Very different is the peculiar basin called Lynn Well. Lynn Deeps is the name given to the deep water of the middle of The Wash (over five fathoms), and Lynn Well lies in the seaward continuation of the Deeps. The Well commences opposite the Long Sand, upon a line drawn from Hunstanton Light and the southernmost Long Sand buoy in Boston Deeps, and runs pretty evenly for eight miles and a half in a north-easterly direction, with an average breadth of about three quarters of a mile. Within this area soundings are never less than 15 fathoms, the greatest depth being towards the southern end (26 fathoms or 156 feet, half a mile N.N.W. of the Well Lightship). On all sides the water shoals very decidedly, but less so toward the north-east. The Well is thus a decided basin and not merely the deepest part of the bay, for the seaward lip is clearly discernible. Unlike Boston Deeps, the Well lies entirely below the level of the great shoal.

The configuration of Lynn Well is such that if it were hollowed out of hard rock it would be called a lake-basin, and it lies in the united continuations of the fen river-valleys, which is also a peculiarity of such basins. It is, however, scooped out of clay; and, though this in itself is no reason why it should not be a glacial lake-basin, it is very probably only a basin in the Boulder Clay of East Anglia. The origin of this singular depression is to be found in the anomalous set of the tides in The Wash, which we now proceed to describe.

The tide which fills the Wash runs southward through the German Ocean, and, spreading across the mouth of the Wash, pours its water into the bay sideways, the flood-tide running in a S.S.W. direction on the western coast, and W.S.W. on the eastern side. The ebb tides run in nearly

opposite directions, or N.N.E. and E.S.E. Off the Knock and the Hook of Long Sand it is high-water on full and change at 6h. ; springs run five miles an hour, ebbs 2½ ; springs rise 23 feet, ebbs 14 feet. When the flood overflows Long Sand the tide runs strong from the east. Near the Woolpack and Sunk Sand the flood runs W.S.W., and the ebb E.S.E. The tide thus flows down the coasts of the Wash, so that it is high-water at Boston and Lynn at about the same time, and about half-an-hour before high-water at Wisbech.

It is clear that the tidal stream flowing down the two coasts in different directions must complicate the tides in Lynn Deeps, and such we find to be the case, and to it the formation of Lynn Well is due. In the Well *the tide is always flowing*, and *completely boxes the compass in the course of 12 hours*, the current continually flowing at a rate of from 2½ to 3 knots, and the rise of spring-tides being 24 feet.

It appears then, that in the middle of The Wash the tidal currents screw round and round, forming, if such an expression be admissible, a slow whirlpool, whose obvious effect is, like a carpenter's centre-bit, to bore a hole. In this way Lynn Well was formed ; and if the limit to which the current acts is not reached (and it is to some extent a surface one), is still in process of deepening.

Another important result of this tidal action is that the suspended matter with which the waters are laden is not deposited in the bed of the Well, for the matter accumulates only at slack-water, which never occurs there. The only deposit which can take place in that locality is what is shoved along the bottom ; accordingly we find the bottom to consist mostly of coarse shingle.

Lynn Well affords an example of an apparent lake-basin, due entirely to tidal action.* Many of the submerged basin-like hollows that occur off our coasts, have the lips formed by bars, and these again need not be due to ice-action. It is necessary, especially in little-known regions, carefully to examine the nature of the lip of suspected lake-basins and the set of the tidal currents, especially as such basins commonly occur in friths, where complicated tides are most frequent. It by no means follows, however, that a basin is not due to ice-action, even where complicated tides are shown to obtain ; if the Well, for instance, were a submerged lake, the tides would still behave as they do now.

MR. GODWIN-AUSTEN long ago showed that the channels of some of our rivers were continued out to sea. This is true of the united channels of some of the Fen-rivers, for a glance at the Admiralty charts shows that a channel bordered by the 10 fathom-line runs seaward for at least 24 miles beyond the mouth of The Wash. The great bank, whose highest portions are known, off the Norfolk coast, as the Dudgeon Shoal, Race Bank, Docking Shoal, and Burnham Flats, forms a great submerged peninsula 24 miles long, and from 16 to 20 miles broad, which marks the extent of an ancient coast-line. Similarly on the Lincolnshire coast a great shoal, having the Inner Dowsing Sand, the Protector, and other overfalls, as its highest parts, marks an old coast-line running almost due north from about 10 miles east of Ingoldmells, beyond the Humber, from whose mouth it is distant 20 miles. Between these great shoals the submerged channel above-mentioned runs.

Speaking generally, the bottom of The Wash is composed of fine and coarse sand and shingle. The sand is white, brown, or grey, and in many places full of black specks, some of which are ilmenite, but most of them fragments of peat. Flat pebbles of hard peat, bored by Pholades, are also found, and are not unfrequently cast up on the sands, chiefly on the Lincolnshire coast, and most abundantly north of Wainfleet. These peat-masses attest the former seaward extension of the peat.

The sands proper, or those which rise above low-water mark, consist of

* We are not sure that MR. SKERTCHLY'S explanation of the origin of Lynn Well is entirely correct, for it is not a hole such as might be formed by a whirlpool, but a long, narrow trough. This trough may be a portion of the ancient valley of the united Fen-rivers, and the tidal action which he describes may have kept it from being silted up.

fine sand and gravel. The Gat Sand, for instance, near Batchelor's Brawn, consists of fine sand, but in other places the sand is coarse, with scattered pebbles, and at about nine inches below the surface the material is fine gravel. The sand on the northern and southern sides of the Thief Sand is fine, hard, and yellow; but on the highest portions the material is very fine, almost like silt, with patches of clay. Fragments of hard peat are washed up on this sand, and specks of the same are abundant in the sand itself in some places. Long Sand is composed of a fine hard sand, with pellets of clay interspersed. In places the sand becomes coarser and full of dead shells. This generally happens where the bank is lower than usual.

I do not believe that the Long and Roger Sands are merely banks of sand and gravel, but look upon them as hills of clay (Kimeridge or Boulder Clay) covered with those materials. If so, they are the modern counterparts of such ancient islands as Whittlesey and Eastrey.

The coast from the mouth of the Witham northward is formed of very fine silty sand or clay, and round the base of the bay only, at some distance from the mainland, is good hard sand to be found. As we proceed northward the coast gets sandier, till at Skegness a beautiful stretch of sandy beach forms the pride of the watering-place. The silt above mentioned is the only Wash-deposit besides sand and gravel. It is only found about high-water mark, and consequently hugs the shore.

That the sands of the Wash are continually increasing has been known as long as the bay has been navigated, and is attested by their great present extent as compared with their former area. But the sands not only increase, they *shift*. The great masses, such as the Gat and Long Sands, it is true, do not alter their position greatly, but the channels are so variable that boats carry sounding-poles and use them daily. A fisherman would not think of going down certain channels from which he had been absent a week or two without sounding.

The deposit now forming in The Wash is almost entirely brought up by the sea. The rivers bring only an inappreciable quantity of sediment from the high-lands beyond the fen, even in times of flood. This is shown by the fact that when the land is drowned by freshets the grass is never soiled, although the flood may be out for weeks. The fact is, most of the sediment is thrown down before the rivers enter the fen, and in this way are formed the alluvial meadows for which the Ouse, the Nene, the Welland, and, to a less extent, the Witham are renowned. If the rivers brought down sufficient material to form deltas, these would be situated at the entrance to the fens, and not at the true river-mouths.

The origin of the sea-borne detritus is not difficult of detection. The water flows down the coasts of Yorkshire and Lincolnshire, which are rapidly wasting, and to this source we must look for the ceaseless supplies of sand and silt which daily encroach upon the waters of The Wash. Most of the material, especially the coarser gravel and sand, is almost certainly carried along the bottom of the sea, and not rolled along the beach or suspended in the water. The finest material, which forms silt, is chiefly suspended in the water. I have taken samples of water across The Wash from off Heacham to Wainfleet, and in every case have found traces of fine sand or clay, or both. The specimens were taken from the bottom and at half depth. Unfortunately, only one line of collection could be run, and that under unfavourable circumstances. The smack was pitching so heavily that we could only filter out the sediment and stow away the filter-paper, a proceeding which prevented any precise determinations. Still, although we cannot yet say how much sediment is brought in by the tides, the fact was established that an appreciable quantity is so carried in suspension. It may be useful to describe the method taken to obtain the water samples. A fourteen-pound lead and lead-line were used in the ordinary manner. After many trials a common soda-water bottle was hit upon to hold the water. It was stropped and snaked like a buoy, with a loop left at the bottom for the line to be attached to. The stropping was carried up to the neck of the bottle, and the ends left about four inches above the neck. These ends were run through a sound cork and formed a loop at its top. When the cork was in the bottle the strings of the stropping were loose, when the cork was pulled out they held it fast. The line was

so attached to the bottle that in heaving no strain was on the cork. When the lead grounded a smart jerk freed the cork, the bottle filled and was drawn up. The jerk of the cork could be distinctly felt in 25 fathoms water and the whole worked admirably. The cost of such an apparatus, including everything, is about 3s. 6d.

The quantitative results obtained are unreliable in consequence of the way the smack had on her at the time of heaving. It takes a minute or so for the bottle to free itself of air, and unless the vessel is steady at the time this cannot be had. Often the bottle came up, especially in shallow water, only half full, and always the contents hissed and frothed with the imprisoned air like the delectable liquid the bottle was formed to contain. Calm weather is all that is requisite to ensure success, and that I did not get.

We have stated that the Fen-silt is derived from the sea, and that it is still in process of formation. The coarser material, sand and gravel, is deposited first, and the finer matter, silt, only in still water. On the coast the deposition is slightly different from that in the estuaries. In the former case the sand is deposited nearly up to high-water mark. The water which overflows the bank is then only the end of the flood, the slack, and the beginning of the ebb, consequently the current is never strong. During the slack the flocculent matter which forms silt is deposited, and the slight movement of the ebb and flood is not sufficient to disturb it. When the bank is in this way raised a little higher the Glasswort (*Salicornia herbacea*), locally known as Samphire, begins to grow. Its stems greatly facilitate the deposition of silt, which now rapidly accumulates, until at length only very high spring tides can overflow it. It has now become salt-marsh, and the typical marsh-flora establishes itself. The samphire-marsh is always distinguished from that which, having become covered with verdure, is called green marsh. They occupy determinate levels as under :—

Samphire Marsh, 8·6 feet above Ordnance Datum, or 18·54 above low-water springs.

Green Marsh, 11·0 feet above Ordnance Datum, or 19·86 above low-water springs.

The present level of the highest part of the green marsh, just outside the banks, near the Witham, is 13·25 feet above Ordnance Datum, and 23·11 feet above low-water springs at Clayhole.

In the estuaries the silt is deposited over the entire bed at high-water slack, and when the scour of the river is good most of this is cleared away during the ebb ; but when the rainfall is defective and the river is low the silt accumulates with disastrous certainty.

The surface of the warp laminæ are often ripple-marked, but even where this is not apparent to the naked eye, it can always be detected by the microscope. As the ripple-marks are always broadside-on to the stream, they afford a means of determining the set of the currents which have deposited the silt in the interior of the Fenland. To accomplish this, however, an immense number of specimens must be examined, and the points of the compass marked on them before they are removed from the ground.

The disengagement of air from the dry silt, on the rising of the tide, often causes the surface to assume a pimply appearance, and flakes float away and are carried to higher levels. Sometimes, when the water is still, its surface is covered with floating fragments of silt, and a considerable quantity must thus be removed in the course of years.

The accretion of land has been going on in some part of the Fenland from the earliest times. In estimating the rate of this accretion, we must remember that not thickness only, but horizontal extent, must be taken into consideration. We have no data for estimating the rate of pre-historic accretion, but the rate since the Roman occupation can be approximately estimated.

The original position of the Roman banks, in reference to the sea, cannot now be determined ; hence we are unable to say how much (if any) land was reclaimed by them. The following are the approximate quantities reclaimed during the subsequent periods :—

Date in Centuries.	Acreage of Enclosures.	Maximum Breadth in Miles.	Minimum Breadth in Miles.	Position.
2nd to 17th	35,000	4·5	2·07	Entirely along the base.
18th	19,000	1·7	0·92	Base, and E. Holland (in Lincolnshire).
19th	10,000	1·0	0·60	Base, and E. Holland (in Lincolnshire).
2nd to 19th	64,000	5·0	Base 3·45 E. H. 0·44	Base, and E. Holland.

Four points require consideration in this question :—*First*, that on each side of a line, called the Axis of Accumulation, which runs from about Lynn Knock to Whaplode Church, the accretion has been nearly equal, as is shown by the area of the embanked lands, of the marsh, and of the barren sands ; and that the watershed is roughly parallel with this axis. This fact was pointed out and the term applied by CAPT. VETCH in his Report on the Norfolk Estuary Scheme, 1849. *Second*, that along the Norfolk coast the accretion has been *nil*. *Third*, that along the base of the bay the accretion has been most rapid. *Fourth*, that the accretion on the East Holland coast has been small, and the inclosures, with the exception of about 1,200 acres south of Wainfleet, have been made in the present century.

With respect to the Axis of Accumulation, we notice that the sands lie closer to it on the Holland than the other coast, though the areas are equal. PROF. GORDON remarks that, "On this axis of accumulation Herring Sand, Hook Hill, Mare Tail, Roger Sand, and Long Sand are being gradually shoved up to Holbeach, Moulton, Gedney, and Fossdyke sea-banks ; and, in the course of time, after various temporary changes of direction, as it were, struggles for independent existence, the sea-channels between Mare Tail and the adjacent Hook Hill Sands have closed up, these sands being no longer islands, but united to the main body of the sands on the Holbeach shore. The exact movement of the sands since any remote period cannot be ascertained, there having been only one accurate survey of them as a whole ; but if we give the compilers of early charts credit for having laid down only such channels and sands as existed, these charts afford strong evidence that the movement of the sands referred to has taken place gradually. The rate of this movement of the sands towards the sea-banks within given periods depends mainly on the changes in the relative positions or advances of the sea-banks. Each successive advance is a cause of acceleration—is a new impetus to the motion in question."*

It is here clearly pointed out that the effect of sea-banks is to facilitate the accretion ; hence in estimating the rate of accretion by means of the sea-banks it must be remembered that the results are greater than they would be on an unwalled coast-line.

Taking the quantities given in the foregoing table, we obtain for the base of The Wash the following rates of accumulation :—

Dates.	Maximum Rate per Annum.	Minimum Rate per Annum.	Mean Rate per Annum.
	Feet.	Feet.	Feet.
Between 2nd and 17th centuries	15·84	1·76	7·29
During 18th century	89·76	21·12	48·65
„ 19th do.	70·41	13·20	31·68
Mean rates for 1,700 years ...	59·00	3·88	10·73

* Report on Linc, Estuary Bill, p. 6,

The mean rates in the above table are obtained by measuring the breadth at every mile, and taking the average of these measurements. This is obviously more correct than taking the mean of the greatest and least breadths. The average rate of accretion for the base of the Wash, between the rivers Welland and Ouse, is therefore 10·73 feet per annum. The effect of embanking green marsh in promoting the accretion of silt is shown forcibly in the above table; thus, between the 2nd and the end of the 17th centuries, no new banks were raised; whereas in the 18th century, when embanking was actively pursued, the minimum rate was greater than the maximum for the preceding 1,500 years, and the mean rate was more than three times the maximum of the long antecedent period. These new lands, be it remembered, are not enclosed till they have become green marsh, so that the above rates show the actual increase of dry land, and not that which has been reclaimed from the tide-way. Indeed, as yet, the only lands enclosed are green marsh, and though at least two admirable schemes have been brought forward to reclaim the banks below high-water mark, they have fallen through, like most comprehensive fen-schemes, for want of pecuniary support, and from short-sighted local opposition.

The accretion along the sides of The Wash has been very much slower. Indeed, so far as the Norfolk coast is concerned, it may be regarded as *nil*, for with the exception of the marshes at the mouth of Wolverton Creek, inclosed in the 18th century (with additions in the latter part of the 19th), no land has been embanked along that coast. At the present time a fringe of green marsh extends from Hunstanton Station southwards to North Wootton, with a minimum breadth of about two chains, a maximum by Wolverton Creek of 0·75 mile, and a mean of 0·213 mile. As this coast is protected by banks of Roman date, we have an average rate of accretion of but 0·66 feet per annum.

On the Lincolnshire (East Holland) coast the rate of accretion is somewhat greater, and, with one exception, all the enclosures since the erection of the Roman banks have taken place during the present century. The exception consists of an enclosure, made last century south of the River Steeping, of about three miles in length by an average breadth of 0·4 miles. The mean breadth of accretion, including green marsh, along this coast is 0·59 miles, which is pretty evenly distributed, the maximum being less than one mile, and the minimum than 0·25 mile. This gives as the average rate of accretion 1·83 feet per annum.

The mean annual rates therefore stand as under :—

			Feet.
Base of Wash	... mean rate	... ...	10·73
East Holland Coast	do.	... ...	1·83
Norfolk Coast	... do.	... ...	0·66

that is to say, the rate of accretion along the base of The Wash is nearly six times as fast as on the East Holland coast, and more than 16 times as rapid as on the Norfolk coast. The rate along the East Holland coast is nearly three times as great as along the Norfolk coast. S. B. J. S.

CHAPTER 12. ECONOMICS.

Building-stones.

The only good building-stone to be found in this area is the brown sandstone which forms the upper part of the Lower Greensand and is known locally under the name of Carstone. This was formerly quarried at several localities, but MR. WHITAKER, writing in 1882, says, at Snettisham only was the Carstone worked in the form of dressed blocks for ashlar masonry. It hardens on exposure, is known as gingerbread-stone, and has a pleasing look, especially in old buildings where more or less covered by lichen.

The stone quarried at Snettisham has been largely used in the construction of the buildings of the new town of Hunstanton, and also for the stations on the railway between Lynn and Hunstanton. MR. WOODWARD remarks that many of the buildings in this stone are erected without mortar, the blocks being arranged in layers and held together by stone courses at the corners which are cemented.

The hard beds of the Lower Chalk have been used in several localities as a rough walling-stone and in the construction of small sheds and outhouses.

Bricks.

There are five formations within the area of Sheet 69 which yield material for brick-making: (1) the clay in the Lower Greensand; (2) the Gault; (3) brick-earth associated with the Chalky Boulder Clay; (4) the Brown Boulder Clays and loams; (5) the Fen-clays.

In the first there are brickyards at Snettisham and Heacham. The second has not been utilised in this area, so far as we are aware, though it has been so used in the district to the southward (Sheet 65). The third material is employed for making bricks near Anmer, Great Bircham, and Docking. The brown clays are worked at the Hawkers Hill Brickyard, between Burnham Westgate and Burnham Deepdale, and also at Holkham Brickyard on the border of the adjoining sheet (69) to the east. MR. CAMERON was informed that bricks had been made of the same clay at Brancaster, though there is no brickyard there now.

The clays of the Fenland have been described on p. 95. Many brickyards exist, especially near Boston and Holbeach; great numbers of bricks are made, but they are not of first-class quality. MR. SKERTCHLY observes that "the bricks are very poor, being soft, friable, and often ill-shaped and cracked. They are generally burnt in kilns, but often when farm-buildings are about to be erected the clay is dug on the spot, and the bricks are fired in clamps. . . . The clay is always mixed with sand or warp for brick-making, but even then shrinks

greatly [in the burning]. The following examples will show this :—

1. Boston East Brickyard, High Bridge Drain.

Size of mould ...	...	...	10 × 5 × $3\frac{1}{4}$ inches.
Size of burnt brick	...	...	$8\frac{1}{2}$ × $4\frac{1}{4}$ × $2\frac{5}{8}$ inches.
Shrinkage of mass	...	...	27·7 per cent.

2. Cow Bridge Brickyard, Boston.

Size of mould ...	...	...	10 × 5 × $3\frac{1}{4}$.
Size of burnt brick	...	...	9 × $4\frac{1}{2}$ × 3.
Shrinkage of mass	...	...	25·2 per cent.

3. A Brickyard close to the last.

Size of mould ...	...	...	10 × $4\frac{1}{2}$ × $3\frac{1}{4}$.
Size of burnt brick	...	...	9 × $3\frac{3}{8}$ × 3.
Shrinkage of mass	...	...	37·2 per cent.

Marl.

The Chalky Boulder Clay which covers so much of the higher ground is generally too calcareous to be burnt into bricks, but has been dug very largely for marl to spread on the land (see p. 74).

In the neighbourhood of Massingham it was customary in the middle of last century to spread about 70 loads of marl over an acre of ground. Some farmers, according to YOUNG,* tried 30 loads more, but without success. In certain cases it was found beneficial to lay on 35 to 40 loads first, and in three or four years time to add as much more, by which means the marl became better incorporated with the soil.

Springs.

The most copious springs in the district under description are those which are thrown out at or near the base of the Chalk.

The springs at Grimston, just beyond the southern border of Sheet 69 have been mentioned in the Memoir on Sheet 65.

MR. WHITAKER contributes the following remarks on the Babingley River :—The main springs in this valley rise about half a mile above Flitcham Abbey. Above this point the stream is a nailbourne, and water only runs continuously when heavy rains have raised the underground water-level. In February, 1883, there were detached sheets of water above the Flitcham springs, higher up the run was more or less continuous, but at last broken up again and ending in a pool and wet ground below Massingham Station. There was also water up the side-valley to the north.

Appleton.—Strong springs rise from the base of the chalk in Denbeck Wood, east of Appleton, and are utilised for the supply of Sandringham House, the waterworks being at Appleton. MR. F. R. BECK, writing to MR. WHITAKER in 1894, stated that the water from these springs is excellent, and the supply never failed till 1893, when the quantity decreased seriously in August and failed altogether at the end of October. The water began to flow again at the beginning of December, and the estate was wholly supplied again on December 14th. The deficiency in 1893 was overcome by pumping water from a shallow spring at the north end of Sandringham House.

Shernborne.—A strong spring issues from the Chalk at Shernborne, the water being doubtless held up by the thin layer of clay which represents the Gault in this neighbourhood.

At *Barrett Ringstead*, about a mile south-east of Hunstanton Station, there is a chalybeate spring which rises from the middle of the Lower Chalk

* YOUNG's "Agriculture of Norfolk," p. 402.

probably about 20 feet above its base. The existence of such a spring in Chalk is unusual, and is probably in this case to be explained by the occurrence of a fissure traversing the Chalk and the Red Rock below so that there is a communication with the underlying Carstone. The ferruginous sandstone is probably saturated with water, and a local fissure may allow this water to escape upward and mix with that which percolates down the valley in the Chalk.

In the eastern part of the Chalk area the position of springs in the valleys varies with the wetness of the season. On this subject MR. WOODWARD contributes the following observations :—In wet weather the Wensum, which is said to take its rise at Wickend Pond north of Tatterset, rises at higher and higher levels towards Barmer, according to the amount of the rainfall and the consequent saturation of the Chalk; at such times numerous small sheets of water or meres occur here and there in the valley.

The valley along which the railway runs from Stanhoe Station to Burnham Westgate is always dry in the summer, but during the winter months a stream rises in it and flows through Burnham, commencing to run after the autumnal rains and continuing above ground generally until May.

Of the spring about half a mile west of Bircham Newton MR. REID writes :—From the character of the channel and the abundance of water-plants the stream is evidently perennial. About 10 chains to the south there is a pond overgrown with sedges evidently on the site of an occasional spring-head. Lower down the valley at Fring more springs occur.

MR. BARROW found that at the village of Bagthorpe water is from 15 to 20 feet below the surface, while a little northward it often comes to within a few feet of the surface. Between Bagthorpe and Syderstone the water used to issue from the Chalk in a strong spring, which was built over, but for some years past it has either ceased entirely or runs with a small flow.

APPENDIX I. WELL-SECTIONS.

WELLS AND BORINGS IN THE AREA OF SHEET 69.

LINCOLNSHIRE.

BOSTON.

Market Place, 1828 (May 3rd to August 3rd).
From THOMSON'S "History of Boston."

——	THICKNESS.		DEPTH.	
	Ft.	In.	Ft.	In.
Loose earth	12	0	12	0
„ „ mixed with silt	12	0	24	0
Very hard earth, mixed with stone	12	0	36	0
Very strong earth, mixed with clay	14	0	50	0
Clay and shells	45	0	95	0
Dark clay and large flints	35	0	130	0
Clay, stones, and shells	20	0	150	0
Clay and large stones	16	0	166	0
Very dark clay and stones	13	0	179	0
Clay and stones	11	0	190	0
Very dark clay and shells	110	0	300	0
Dark clay	28	0	328	0
Light slate-coloured clay, with large shells	22	0	350	0
Dark clay and shells	65	0	415	0
Dark clay	38	0	453	0
Clay, with great quantity of shells	31	0	484	0
Shells, shingle, dark clay, and sharp sand	2	0	486	0
Remarkably fine sharp sand	3	0	489	0
Ditto and dark clay	9	0	498	0
Clay and very large shells	7	0	505	0
Shingle, flints, and shells	3	5	508	5
Rock. MESSRS. TUXFORD, who sank the well, say:— "It is supposed possible that some hard substance may have fallen in, causing the appearance of 'rock' at these depths"	2	1	510	6
Stones, mixed with clay	12	4	522	10
Clay, shells, and flint	7	0	529	10
Stone, shells, and rock	18	2	548	0
Very dark clay	7	0	555	0
Very fine white sand	11	0	566	0
A dark umber-like earth, soft and hard by turns ...	6	0	572	0

In the Fenland Memoir (pp. 211, 279) MR. SKERTCHLY classified the beds as follows, but with some error in the figures on the latter page:—

Fen-beds, 24.
Boulder Clay, 460 (or Glacial Beds, 420).
Pre- or inter-Glacial beds, 88 (or 87).

There is also some error in speaking of the record of "clay, shells, and flint" at the "depth of 583 feet," as this is more than the depth of the boring. The lowest bed of that character is at about 530 feet.

MR. SKERTCHLY regarded the whole of the section of 572 feet to be in Quarternary beds.

This boring was subsequently discussed by MR. JUKES-BROWNE,* from whose remarks the following are quoted :—

"Depending on this record and mainly on the fact that between the depths of 523 and 530 feet 'clay, shells, and flints' are said to have occurred, MR. SKERTCHLY regards the section as giving evidence of the extension of the Glacial series to the enormous depth of nearly 600 feet below Boston.

"I cannot but think, however, that the evidence on which this supposition rests is too weak and uncertain to support so startling a conclusion. The description of the beds said to have occurred in the last 80 feet is certainly extraordinary, but [unless samples have been preserved] a boring can never be regarded as of the same evidential value as a section which has been open to observation, and this boring is 50 years old, so that no questions can be asked of the well-sinker. Everyone who is accustomed to the reports of such persons is aware of the extraordinary terms they sometimes use, of the necessity there is for personal cross-examination, and of the liability to error arising from stones and other substances falling into the bore ; this error is particularly difficult to eliminate, and it may account for some of the appearances in the present case.

"Furthermore it is always necessary to translate such accounts into geological language, and it is not always safe to accept the well-sinker's terms in a literal sense. Now in this particular record frequent mention is made of *shells*, *shingle*, and *flint*, and MR. SKERTCHLY lays great stress on the last of these because he thinks 'this substance can hardly have been mistaken for any other material.' In Cambridgeshire, however, the term 'flint' is said to be sometimes applied to hard beds and concretions in the Jurassic Clays. Speaking of a rocky band in the Oxford Clay, PROF. H. G. SEELEY says 'the workmen call it *flint*, a name I have also found given in the surrounding district to the septarious concretions in the clays.'†

"It is quite possible, not to say probable, that the greater part of this boring lies in the Kimeridge and Oxford Clays ; especially as in the only other deep boring near Boston the base of the Boulder Clay was found at a depth of 166½ feet. Beds of rock and sandstone are known to occur in and between these clays not far to the southward, and the isolated reef at Upware attests the local and occasional development of the Coral Rag. . . .

"Now assuming that the lower part of the boring is in the Oolitic Series, it becomes important to determine, if possible, the base of the Boulder Clay ; and in the first place it may be noted that the boring at Fossdyke (only seven miles south of Boston) reached the bottom of this clay at a depth of 166½ feet, passing immediately into Kimeridge Clay with septarian bands which was bored to a further depth of 159½ feet. If we examine the account of the Boston well we find that stones are repeatedly mentioned as occurring in the clay down to a depth of 190 feet, but that below this [level] there is no recorded occurrence of stones throughout a thickness of 294 feet. All this portion of the section is described as 'dark clay with shells,' except a band in the middle, 22 feet thick, of 'light slate-coloured clay with large shells.' Such a description applies far better to the Kimeridge or Oxford Clay than to Boulder Clay, for it would be surprising that no stones should have been met with in boring through a thickness of nearly 300 feet of Boulder Clay. Moreover, if we place the base of the Boulder Clay at 190 feet the section then agrees very fairly with the more recent and more accurately described boring at Fossdyke."

It was then pointed out that the real difficulty lay in the interpretation of the lower 88 feet of the boring, which is stated to have passed through a varied series of sands, clays, and rock-beds ; and I suggested that these might be a local development of Corallian Beds between the Oxford and Kimeridge Clays. A reconsideration of the matter has, however, induced me to alter my opinion. The thickness of Oxford Clay which comes in beyond the western border of the Fenland in Sheet 70 is very small ; its easterly dip is also so small as to be inappreciable in the brickyard exposures, and in all probability it becomes really *nil* under the central part of the Fenland.

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* *Quart. Journ. Geol. Soc.*, vol. xxxv., p. 418 (1879).
† *Ann. and Mag. Nat. Hist.*, ser. 3, vol. x., p. 104.

Now Boston is only about 15 miles from the outcrop of the Kellaways Beds near Sleaford, and if we allow a dip of half a degree throughout the whole distance (which is probably an excessive estimate) the thickness of beds brought in below Boston will be only 630 feet, which is only 58 feet more than the 572 feet proved. Moreover, the Kellaways Beds do consist of alternations of white sand, clay, and sandy rock with fossils.

Consequently I am now inclined to believe that this boring traversed the whole of the Oxford Clay and the Kellaways Beds, and may possibly even have entered the Great Oolite clay. The succession of formations pierced by this boring may therefore be summarised as follows :—

		Feet.
Fen Beds ...	Loose earth and silt	24
Boulder Clays 166 feet.	Hard earth with stones	26
	Clay with stones, flints, and shells	140
Kimeridge and Oxford Clays 294 feet.	Dark clay with shells	138
	Light-coloured clay with shells	22
	Dark clays with shells	134
Beds at and below base of Oxford Clay, 88 feet.	Fine sand and clay	21
	Stones and rock	5½
	Clay with stones and shells	19½
	Stone, shells, and rock	18
	Dark clay	7
	White sand	11
	Brown earth	6
		572

A. J. J-B.

BOSTON.

J. FAREY, in a letter to SIR J. BANKS, 1808, refers to a deep boring here, and doubts the chalk, small pebbles, and flints said to have been got deep down, thinking that they have fallen down from above. The section is given as follows :—

	Feet.
Alluvial silt, clay, sand, and gravel	37½
Clunch (? clay)	441

BOSTON, 1746. ? Sunk by T. PARTRIDGE.

——	Thickness.	Depth.
	Ft. In.	Ft. In.
Sand	3 0	3 0
Made earth (old surface)	5 0	8 0
Stones and gravel	3 0	11 0
Clay	5 0	16 0
Stones, rubble, sort of chalk	3 0	19 0
Clay with very small handstones not pierced ...	173 0	192 0

It may here be stated that no fewer than four deep borings have been made at Boston in search of water. The dates of these are as follows :—

Date.	Maker.	Depth.	Reference.
1746 ...	T. Partridge ...	192 ...	Gent. Soc. Spalding.
1783 ...	G. Naylor ...	478 ...	Phil. Trans.
1826 ...	T. Wilks ...	560 ...	History of Boston.
1828 ...	Tuxford ...	572 ...	*Ibid.*

SKIRBECK QUARTER, BOSTON.

21·9 feet above low-water in Boston Deeps.

From Mr. W. H. WHEELER.

		Thickness.	Depth.
		Ft. In.	Ft. In.
Alluvium	Clay and Silt: Silty clay	5 6	5 6
	Clay and Silt: Blue clay	3 6	9 0
	Clay and Silt: Silty clay	6 0	15 0
	Clay and Silt: Soft buttery clay, more moist	2 10	17 10
	Clay and Silt: Silty clay	0 5	18 3
	Peat, sandy at bottom	1 4	19 7
	Sand: Sharp sand, especially last 4 inches	0 9	20 4
	Sand: Sharp sand, greyish yellow; water rose	0 11	21 3
	Sand: Sharp sand	0 11	22 2
	Sand: Sand, clay, and small stones	0 6	22 8
	Sand: Sharp sand	2 10	25 6
	Boulder Clay—Clay with chalk-stones	0 4	25 10

BOSTON.

Nearer the road than the above.

Communicated by MR. W. H. WHEELER.

		Thickness.	Depth.
		Ft. In.	Ft. In.
Fen Beds	Clay and silt	17 9	17 9
	Peat	1 6	19 3
	Sand	4 9	24 0
Boulder clay		0 6	24 6

BOSTON.

Boring at the Grand Sluice on the River Witham, 1½ miles above the Docks.

Communicated by MR. W. H. WHEELER.

		Thickness.	Depth.
		Feet.	Feet.
Fen Beds	Alluvial Soil	10	10
	Clay	2	12
	Soft clay	1	13
	Soft black clay, with cockle shells	4	17
	Very soft clay	5	22
	Peat	1	23
	Sand	5	28
Glacial Beds	Hard clay	1	29
	Sand	1	30
	Boulder Clay of a black colour, with small chalk-stones, bored for	9	39

N.B.—The Boulder Clay here is much blacker in colour than at the Docks and has less chalk in it.

BOSTON.

Borings made to test the ground before the construction of Boston Docks. Communicated by MR. W. H. WHEELER.

		THICKNESS.	DEPTH.
	NO. 1.	Feet.	Feet.
Soil and rubbish		4	4
Fen Beds	Loamy clay	1	5
	Brown clay (a good brick clay)	4	9
	Loam and silt	1	10
	Brown clay	2	12
	Clay with specks of peat	2	14
	Clay and peat	1	15
	Peat and sand	3	18
Glacial Beds	Sand and yellow clay	1	19
	Boulder Clay	4	23

BOSTON.

		THICKNESS.	DEPTH.
	NO. 2.	Feet.	Feet.
Blue clay		4	4
Brown clay		2	6
Blue clay		5	11
Clay with specs of peat		4	15
Clay and shells		3	18
Sand and peat		1	19
Boulder Clay		4	23

BOSTON.

Borings at the Witham Outfall Works near Clayhole. Communicated by MR. W. H. WHEELER.

No. 1 on the ENCLOSED LAND.	Feet.	No. 2 on the FORESHORE.	Feet.	No. 3 at LOW-WATER MARK.	Feet.
Alluvial soil	5¾	Sand and silt	3	——	
Brown clay	3	Brown clay	3	——	
Blue clay	1	Blue clay	3	Blue clay	6
Peat	0½	Peat	1	Peat	1
Sand	0½	Sand	0½	Sand	1
Boulder Clay	—	Boulder Clay	—	Boulder Clay	—

LADE BANK ENGINES. East Fen, north of Boston.

From MR. W. H. WHEELER (see "Geology of the Fenland" p. 280) ? a well or a boring.

		Ft.	In.
Fen Beds ...	Clay	4	0
	Peat	0	6
	Soft blue clay	3	0
	Peat with pieces of trees	?	6
Boulder Clay—Hard clay with chalk-stones ...		22	0
		30	0

HOLBEACH. The Eight-sailed Mill.

From "The Geology of the Fenland," probably from information obtained by MR. SKERTCHLY.

		Feet.
Fen Beds	Soil	3
	Silt	2
	Sand	6
	Clay with shells, full of salt-water	19
		30

FOSSDYKE. Coast Guard Station, 1875 (? abandoned).

Made and communicated by MESSRS. S. F. BAKER & SONS.

——	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Depth of well (the rest bored), partly in sand and gravel	—		21	0
Sand and gravel	57	0	78	0
Yellow sandy clay [? Boulder Clay]	37	0	115	0
[Boulder] Clay, light blue, with chalk-stones ...	51	6	166	6
Dark [Kimeridge] Clay, with septarian bands ...	159	6	326	0

SUTTON. THOMPSON'S "History of Boston."

From MR. W. H. WHEELER and from Mr. C. B. ROSE, *Geologist*, 1843, p. 77.

——		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Fen Beds ...	Clayey warp	16	0	16	0
	Moor or peat	3 to 4	0	20	0
	Soft moor, mixed with shells and silt	20	0	40	0
Boulder Clay	Marly clay	1	0	41	0
	Chalk rock	1 to 2	0	?42	0
	Clay mixed with chalk-stones, gravel, and water	93	0	135	0

STICKNEY.

From MR. SKERTCHLY'S "Geology of the Fenland," p. 276.

Actual site not specified, probably a boring at some spot west of the village.

		Ft.	In.
Fen Beds	Clayey silt	4	0
	Peat with trees	0 to 0	6
	White sand	2	0
	Dark gravel mixed with clay and sand	6	0
Kimeridge Clay.	Dark blue clay	32	0
	Very large septaria	2	0
	Dark blue clay	—	
		Over 46	6

LONG SUTTON.

A boring. Information from Mr. WILLIAM SKELTON.

		Feet.
Fen Beds	Silt and fine sand	47
	Gravel and sea-shingle	10
Boulder Clay.	Blue clay with small pieces of chalk and occasionally flints, about ...	100
Kimeridge Clay.	Blue clay without chalk-stones, about...	116
		273

This was the depth of the boring in 1885 when it was stopped as no water was obtained. We are informed by MR. W. H. WOODCOCK, of Long Sutton, under date October 20th, 1897, that the boring was not continued, and that the tube still remains in the ground as it was left in 1885.

NORFOLK.

BURNHAM MARKET, OR BURNHAM WESTGATE.

Information obtained by MR. CAMERON and MR. G. BARROW.

1. House facing Norton Road.

   Sand and gravel 16 feet
   Hard chalk ... 24 „ } 40

2. Cobbler's Hill Farm. Chalk 134 feet. MR. G. BARROW notes a well at Cobbler's Hill Plantation as 130 feet to water, the level of which varies, though the well is never dry.

3. Sussex Farm, in the valley about 1¾ miles west of the town. Chalk, 100 feet, the upper part marly, and with a thin covering of gravel.

4. Friar Thorn Farm, on the main road to Docking about 1½ mile from the church.

   Boulder Clay 30 feet
   Chalk ... 150 „ } 180 feet.
   Depth of water in April, 1883, 40 feet.

5. Cradle Hall, south-west of the last. Well said to be 200 feet deep, but probably not so much, as it went dry once in a dry summer. Depth of water in April, 1883, 30 feet.

Castle Rising.

Rising Lodge Farm, on the high-road, a mile south of Castle Rising. Sunk and communicated by J. Fake, of Norwich, 1881.

Gravel and Sand [Lower Greensand] 105 feet.

Another well sunk about 100 yards east of the above is said to be about 113 feet deep.

Castle Rising.

Cottage at foot of hill, three quarters of a mile east of South Wooton. Sunk and communicated by J. Fake, of Norwich.
Water rose 30 feet

Brick-earth	about	7 feet.
Red clay	„	2 or 3 „
Blue clay	„	29 „
To sand [Lower Greensand] ...		39 „

Docking.

Town well. Information obtained by Mr. G. Barrow.

Boulder Clay (known as brick-earth) ...	30 to 40 feet.
Gravel	30 to 40 „
Fine sand	70 „
Rock (very hard chalk)...	50 „
The total depth being	190

The depth of clay and gravel together was said to be about 70 feet. The well having gone dry some years ago was deepened, and on sinking 10 feet more they came on tabular flint, which crossed the entire bottom of the shaft. On breaking through this water came in and rose very rapidly, and the well has never been dry since. In April, 1883, there was 40 feet of water.

Another account obtained by Mr. C. Reid says that the well is bricked for 60 feet, and that the rest is in chalk with flints to 216 feet. This, however, may refer to another well, as there are said to be two deep wells in Docking.

East Rudham.

Information obtained by Mr. H. B. Woodward.

1. At Railway Station.	Boulder-clay and chalk		34 feet.
2. At Inn by the Station.	„	„	29 „

The water stands about 4 feet deep.

Little Massingham.

Brickyard, south of the church, made in 1882, and communicated by Mr. J Seaman, of Great Massingham.

Clay, light-coloured at top, the rest blue [Loam and Boulder Clay]	100 feet.
Chalk	30 „

SANDRINGHAM.

Trial bore, 1885, made and communicated by MESSRS. T. TILLEY & SON. Plenty of good, but rather hard, water.

			Thickness.	Depth.
			Ft. In.	Ft. In.
Made ground	... ...		7 0	7 0
Lower Greensand	Upper Division	—Sand	6 6	13 6
	Middle Division	Coloured Clay ...	2 0	15 6
		Blue Clay ...	12 0	27 6
	Lower Division	Black sand, hard ...	8 6	36 0
		White sand, hard...	12 0	48 0
		Grey sand ...	14 6	62 6
		Hard Rock ...	0 4	62 10
		Grey sand to rock...	7 0	69 10

An account of a boring (at a different site) made in 1872, given by MR. MANSERGH (to PROF. T. R. JONES, who supplies notes in brackets from specimens), differs considerably, being as follows :—

118½ feet above Ordnance Datum.

			Ft.	Ft.
Red Chalk	...	... ...	6	6
Lower Greensand		Carstone	14	20
	Upper Division	Greensand (brownish-green sand)	10	30
		Stone, with mineral... ...	1½	31½
		Greensand (greenish-brown sand, with nodules of pyrites at top, then sand stained green)	15½	47
	Middle Division	Stiff blue clay (sandy clay) ...	5	52
	? Lower Division	Blue stone (light brown clayey sand)	16	68
		(Black clayey sand) (Light-grey very sandy clay) } thickness not given		
		? Boring left off at	—	100

SNETTISHAM.

Information from MR. CHILVERS (who made the wells).

1. Cottages by brickyard ; well about 20 feet deep in sand.
2. At Grammar School, on rising ground north-east of the Hall ; well about 50 feet deep, with 4 feet of water. The top 6 feet black earth or silt [clayey beds of the Lower Greensand], the rest sand.

STANHOE.

Information about several wells obtained by MR. G. BARROW.

1. The village well was 170 feet deep but has been deepened by 10 feet as it failed in summer. Now 180 feet, of which rather more than 30 feet is clay, the rest is chalk.

2. Great Barwick well, said to be a hundred feet deep or rather more. In winter and spring the water rises to within 30 or 40 feet of the surface, but in the summer it sinks at least 20 feet and sometimes more.

3. Well at cottage close to the railway-station. This is 60 feet deep, 10 feet through marl and 50 feet through hard chalk. The water varies in level; in April, 1883, it was about 30 feet from the surface.

TATTERSET.

Well by brickyard north of Pinkney Hall.
Communicated by MR. MASSINGHAM to MR. H. B. WOODWARD.

		Feet.
Boulder Clay	[Loamy top] Brick-earth	5
	[Marl] White earth	25
	Blue Clay with "golt" of sand that gives springs	14
		44

Supplementary Record of Wells and Borings in other Parts of Norfolk and Lincolnshire.

Lincolnshire.

Allington Hall (Mr. J. E. Welby).

About 4½ miles north-west of Grantham (Sheet 70).
Made and communicated by Messrs. Legrand and Sutcliff (1877).

		Thickness.	Depth.
		Ft. In.	Ft. In.
Dug pit (the rest bored)		—	3 6
Lower Lias	Dark blue clay	23 0	26 6
	Blue clay	45 0	71 6
	Dry blue clay	12 0	83 6
	Blue shale and rock	2 6	86 0
	Blue rock	4 6	90 6
	Black shale and rock	21 6	112 0
	Black rock	3 6	115 6
	Blue stone and shale	28 0	143 6
	Black shale	4 0	147 6
	Black shale and blue rock	8 3	155 9
	Black shale	4 9	160 6
	Black shale and rock	14 0	174 6
	Blue stone	2 6	177 0
	Blue stone and shale	4 0	181 0

Bourn. (Sheet 64.)

Boring at Tongue End Farm, about 5 miles E.S.E. of Bourn.
Communicated by Mr. Edward Easton, C.E., 1894.
Water found at a depth of 190 feet and rose to 60 feet above surface.

		Thickness.	Depth.
		Ft. In.	Ft. In.
Alluvium and Oxford Clay.	Blue clay	50 0	50 0
	Hard brown clay	46 0	96 0
Kellaways Beds.	Hard sandstone	10 0	106 0
	Blue clay	10 0	116 0
Cornbrash.	—Hard stone	7 6	123 6
Great Oolite Clay.	—Clay	17 0	140 6
Great Oolite Limestone.	Hard stone	13 6	154 0
Upper Estuarine Series.	Clay	11 0	165 0
	Stone	1 0	166 0
	Hard brown clay	7 0	173 0
	Clay stones and a bed of shells ...	10 0	183 0
Lincolnshire Limestone.	Hard stone like granite ...	15 0	198 0

BOURN. (Sheet 70.)

Top of West Street. For the Waterworks, 1888.

Communicated by MESSRS. EASTON & ANDERSON. Bored throughout, and tubed to the depth of 89½ feet. Water flowed 4 feet above the surface. Yield, about 300,000 gallons in 24 hours. Subsequently deepened to 120 feet, and gave 864,000 gallons a day.

		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Soil	... ...	3	0	3	0
Drift... ...	Silty sand	3	0	6	0
Oxford Clay ...	Clay	8	0	14	0
Cornbrash, 9ft.	Blue sandstone	1	0	15	0
	Limestone rock	8	0	23	0
Great Oolite Clays, 19ft. 7in.	Blue clay	2	7	25	7
	Dark clay	1	5	27	0
	Green marlstone	1	0	28	0
	Green marl	4	0	32	0
	Clay	2	0	34	0
	Clay and shells	1	0	35	0
	Clay and silty sand	1	7	36	7
	Clay	6	0	42	7
Great Oolite Limestone, 14ft. 5in.	Rock and shells, very hard ...	9	0	51	7
	Light blue clay	1	5	53	0
	Green clay	3	0	56	0
	Green marlstone, with water ...	1	0	57	0
Upper Estuarine Series, 29ft.	Dark blue clay	1	0	58	0
	Dark brown clay	1	0	59	0
	Dark blue clay and shells ...	1	0	60	0
	Blue soft rock. Water (rose 54 feet)	4	0	64	0
	Light-coloured clay and shells ..	1	4	65	4
	Brown clay	1	0	66	4
	Dark brown clay	3	8	70	0
	Brown clay	1	0	71	0
	Dark green clay and silty sand ...	2	0	73	0
	Dark brown clay	1	0	74	0
	Grey clay or pipe-clay	12	0	86	0
Lincolnshire Limestone.	Sandstone, with water... ...	1	0	87	0
	Blue clay and chalk [calcareous matter]	1	0	88	0
	Sandstone rock, with water ...	11	0	99	0

MR. F. S. COURTNEY (of MESSRS. EASTON & ANDERSON'S) writes as follows :—"The water tapped in this district, at a depth of about 98 feet, is very plentiful, and the standing level is in many cases as much as 20 feet above the surface. There are several borings in the neighbourhood, but I do not know of any of the former ones which were tight: in every boring I have examined, a large proportion of the supply finds its way up the outside of the bore-pipe, and, meeting with some of the more friable strata at a higher level, escapes. In this boring a double lining has been provided (10 inches in diameter to a depth of 44½ feet, the rest 5 inches in diameter and reaching nearly to the surface), a sound joint having been made between the two. The boring is, I believe, quite tight. Two borings, made in recent years, within a mile of this boring, for the Spalding Water Company, in which no special care was taken, are unsatisfactory."

According to *The Engineer*, vol. lxv., p. 181 (1888), "this town is the only one in the United Kingdom which gets its supply direct from the source without pumping," referring, of course, to well-supplies only.

BOURN. Spalding Waterworks.*

Made and communicated by MESSRS. C. ISLER & CO., 1893.
? 78 feet above Ordnance Datum.
Pit 6 feet, the rest a boring of 13 inches diameter.
Water rises 34 feet above the ground.
Chalybeate water was found at the depth of 65½ feet and was shut out. The main springs were tapped at 78½ feet, the water then rising very slowly and taking 24 hours to overflow. Deeper the volume increased rapidly and the overflow was 1,872,000 gallons a day at the depth of 100 feet, 2,592,000 at 120, and over 5,000,000 at 134.

		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Made ground		2	0	2	0
Drift.	Clay	1	6	3	6
	Gravel	1	0	4	6
	Clay	2	0	6	6
	Loamy clay	1	0	7	6
Cornbrash, 8½ feet.	Rock and shells	2	0	9	6
	Limestone	6	6	16	0
Great Oolite Clay, 20 feet.	Hard blue clay	4	0	20	0
	Mottled clay	10	0	30	0
	Shaly clay, dark blue and green	1	0	31	0
	Luminous hard blue rock	2	0	33	0
	Dark blue soft rock with shells	1	0	34	0
	Hard blue clay	2	0	36	0
Great Oolite Limestone, 12 feet.	Hard blue rock limestone	7	0	43	0
	Hard blue rock, lighter colour	4	0	47	0
	Harder blue rock, dark green	1	0	48	0
Upper Estuarine Series, 28 feet.	Dark green clay	7	0	55	0
	Hard blue rock	1	0	56	0
	Dark and light green clay	9	0	65	0
	Hard rock	0	10	65	10
	Light green sandy clay	9	8	75	6
	Black clay (peat) [lignite]	0	6	76	0
Lincolnshire Limestone.	Grey porous rock (oolite limestone)	1	6	77	6
	Hard oolite limestone	33	0	110	6
	Very hard rock	5	6	116	0
	Hard limestone	5	6	121	6
	Hard oolite limestone	12	6	134	0

MESSRS. ISLER remark that there are no published records of springs being tapped by boring that yield a larger quantity than in this case.

* See also H. B. WOODWARD'S "Memoir on Jurassic Rocks of Britain," vol. iv., p. 505, and vol. v., p. 334.

BOURN. Great Northern Railway Station. (Sheet 64.)

Made and communicated by MESSRS. C. ISLER & CO.
Good supply of water, rising 19 feet above the surface.

		Thickness.	Depth.
		Ft. In.	Ft. In.
Dug well (the rest bored)...		0 0	6 0
Kellaways Beds.	Hard sandy clay	4 0	10 0
	Sandstone	6 0	16 0
	Hard black sandy clay... ...	7 6	23 6
Cornbrash.	—Hard blue limestone	8 6	32 0
Great Oolite Clay.	Hard mottled clay	8 0	40 0
	Hard clay	8 0	48 0
Great Oolite Limestone.	Rock and shell	4 0	52 0
	Hard rock	3 0	55 0
	Very hard limestone	2 6	57 6
Upper Estuarine Series.	Hard green sandy clay ...	8 6	66 0
	Hard marly clay	9 0	75 0
	Hard chocolate[-coloured] clay ...	21 0	96 0
Lincolnshire Limestone.	Oolite limestone	38 0	134 0
	Hard rock	16 0	150 0

DEEPING, ST. JAMES. (Sheet 64.)

Boring on MARQUIS OF EXETER'S Estate, 1896.
Communicated by MR. H. SYKES, 66, Bankside, London.
Water rises 31 feet above ground.
Level of ground about 10 feet above O. D.

		Thickness.	Depth.
		Ft. In.	Ft. In.
Drift.	Clay and gravel	16 6	16 6
	Clay and sand	1 6	18 0
Kellaways Beds.	Shaly rock	10 0	28 0
	Blue clay	6 0	34 0
Cornbrash.	—Hard granite rock	9 0	43 0
Great Oolite Clay.	Sandy clay	1 0	44 0
	Shaly rock with shells	1 0	45 0
	Hard mottled clay	10 0	55 0
	Shaly rock	3 0	58 0
	Hard brown clay	2 0	60 0
	Clay and shells	1 0	61 0
Great Oolite Limestone.	Very hard shaly rock	13 0	74 0
Upper Estuarine Series.	Shelly clay	32 0	106 0
Lincolnshire Limestone.	Oolite rock	14 0	120 0

DORRINGTON FEN. (Sheet 70.)

Boring at Fox's Farm, 5 miles N.N.E. of Sleaford, made in 1896.
Communicated by MR. JESSE CLARE, C.E., of Sleaford.
Water came in at 150 feet and rose above surface.

		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Oxford Clay and Kellaways Beds.	Clay	26	0	26	0
	Dice [soft shaly clay]	29	6	55	6
	Dice and silt	4	6	60	0
	Dice	7	0	67	0
Cornbrash.	Rock	2	4	69	4
	Clay	3	0	72	4
	Rock	2	8	75	0
Great Oolite Clay.	—Clay	26	1	101	1
Great Oolite Limestone.	Rock, mostly hard	9	8½	110	9½
	Rock with clay bands	2	0	112	9½
	Rock with clay bands	2	2½	115	0
Upper Estuarine Series.	Clay	5	0	120	0
	Rock, very hard	1	9	121	9
	Clay	11	11	133	8
	Clay and dice	6	3	139	11
Lincolnshire Limestone.	Soft rock	4	2	144	1
	Hard rock	9	8	153	9

HECKINGTON. (Sheet 70.)

Boring at the west end of the village, made in 1896.
Communicated by MR. JESSE CLARE, C.E., of Sleaford.
Water overflows at rate of about 6 gallons a minute.

		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Drift.	—Soil and gravel	10	0	10	0
Oxford Clay and Kellaways Beds.	Clay	221	0	231	0
	Rock	4	0	235	0
	Clay	3	0	238	0
	Sandy rock	8	0	246	0
	Clay	9	0	255	0
Cornbrash.	—Rock	7	0	262	0
Great Oolite Clay, 22 feet.	Clay	11	0	273	0
	Rock	1	0	274	0
	Clay	2	6	276	6
	Rock	4	6	281	0
	Clay	3	0	284	0
Great Oolite Limestone, 17 feet.	Rock	9	0	293	0
	Clay band	0	6	293	6
	Rock, very hard	1	6	295	0
	Rock, softer	6	0	301	0
Upper Estuarine, 24 feet.	Clay and stones (or shells) ...	3	0	304	0
	Rock	3	0	307	0
	Clay	16	0	323	0
Lincolnshire Limestone.	Rock	15	0	238	0
	Rock, hard white, with water ...	38	0	376	0
	Clay and shale	1	0	377	0
	Hard rock with a soft vein at 385 feet	23	0	400	0

LITTLEWORTH OR DEEPING ST. NICHOLAS. (Sheet 64.)

Sunk 5 feet 6 inches, the rest bored. Completed November 26th, 1894.
Communicated by MR. HENRY SYKES, 66, Bankside, London.
The yield of water at 2 feet above ground is 20 gallons per minute.

		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Alluvial Deposits.	Clay and silty sand	15	0	—	
	Peat	1	0	16	0
	Brown clay	2	0	18	0
	Peat	2	0	20	0
	Gravel	3	0	23	0
Oxford Clay and Kellaways Beds.	Blue clay	130	0	153	0
	Clay and shells	50	0	203	0
	Shaly rock	7	0	210	0
	Blue clay	16	0	226	0
Cornbrash.	—Hard sandstone [limestone] ...	7	0	233	0
Great Oolite Clay and Limestone.	Mottled clay and shells ...	10	0	243	0
	Hard blue rock with a little water	10	0	253	0
	Brown clay	7	0	260	0
	Sandstone rock	3	0	263	0
Upper Estuarine Series.	Clay and shells	22	0	285	0
Lincolnshire Limestone.	Freestone rock: Water struck at 286 and 308 feet	42	0	327	0
	Pipe-clay	1	0	328	0
	Soft sandstone rock: More water at 332	20	0	348	0
	Sandy clay	2	0	350	0

In this account it is not easy to separate the Great Oolite Beds into a clay and a limestone group, and the two together are rather thinner than usual (only 30 feet).

OSBOURNBY. (Sheet 70.)

Boring made in 1884–5.
Communicated by MR. JESSE CLARE, C.E., of Sleaford.
Water rises above surface during part of the year.

		Thickness.	Depth.
		Ft. In.	Ft. In.
Soil.	—Loose stones and soil	1 6	1 6
Oxford Clay.	Yellow clay	3 0	4 6
	Dark blue clay	14 6	19 0
Cornbrash.	Cornbrash rock	2 0	21 0
	Dark clay parting	0 2	21 2
	Hard blue rock	2 10	24 0
	Dark clay parting	0 4	24 4
	Hard blue rock	0 10	25 2
Great Oolite Clay.	Soft dark brashy clay	3 0	28 2
	Strong dark blue clay and fossils	21 0	49 2
Great Oolite Limestone.	Hard grey rock	0 10	50 0
	Strong dark blue clay	1 0	51 0
	Very hard blue rock	12 0	63 0
Upper Estuarine Series.	Blue mottled clay	1 6	64 6
	Hard blue rock	0 6	65 0
	Light blue clay	6 0	71 0
	Very hard blue rock	2 0	73 0
	Strong blue clay with fossils ...	19 6	92 6
Lincolnshire Limestone.	Very hard limestone	7 3	99 9
	Rock band parting	0 2	99 11
	Very hard limestone	30 5	130 4
	Limestone with thin partings ...	20 6	150 10

QUARRINGTON. (Sheet 70.)

Boring on west side of parish near Rauceby Station, G.N.R., for new asylum. Completed June 21st, 1898. 100 feet above O.D.
Communicated by MR. JESSE CLARE, C.E., of Sleaford.
Abundant supply of water which rises to within 42 feet of the surface.

		Thickness.	Depth.
		Ft. In.	Ft. In.
Great Oolite Clay.	Light clay	2 6	2 6
	Blue clay	25 6	28 0
Great Oolite Limestone.	Hard blue rock	11 0	39 0
Upper Estuarine Series.	Blue clay	29 0	68 0
Lincolnshire Limestone.	Light soft rock	5 0	73 0
	Hard limestone	8 0	81 0
	White limestone	6 0	87 0
	Blue rock	6 0	93 0
	White limestone	5 0	98 0
	Grey limestone	11 0	109 0
	Blue rock	6 0	115 0
	Grey limestone	5 0	120 0

SCREDINGTON, 3½ miles S.S.E. of Sleaford. (Sheet 70.)

Boring by side of roadway in village, 35 feet above O.D. Water overflowed surface.

Communicated by MESSRS. TILLEY, July, 1897.

		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Oxford Clay and Kellaways Beds.	Clay	97	0	97	0
	Rock	2	0	99	0
	Clay	4	0	103	0
	Hard sandy clay	2	0	105	0
	Clay	2	0	107	0
	Loamy sand	14	0	121	0
	Clay	2	6	123	6
Cornbrash.	Rock	5	0	128	6
Great Oolite Clay.	Dark clay	1	6	130	0
	Coloured clay	7	0	137	0
	Dark clay	14	6	151	6
Great Oolite Limestone.	Rock	12	0	163	6
Upper Estuarine Series. 32 feet.	Mixed clay	4	0	167	6
	Dark clay	2	6	170	0
	Mixed clay	4	0	174	0
	Rock	3	0	177	0
	Green clay	3	0	180	0
	Dark clay	6	0	186	0
	Slate-coloured clay	7	0	193	0
	Dark clay	3	0	196	0
Lincolnshire Limestone.	Rock	23	0	219	0

SILK WILLOUGBY, 2 miles S.S.W. of Sleaford. (Sheet 70.)

A boring on land in occupation of MR. DONCASTER on the property of the EARL OF DYSART.

Communicated by MESSRS. WADSLEY & SON, of Horbling, 1891.

		THICKNESS.	DEPTH.
		Ft. In.	Ft. In.
	Clay and soil	8 0	8 0
Cornbrash.	—Rock	3 0	11 0
Great Oolite Clay.	—Blue clay	20 0	31 0
Great Oolite Limestone.	Rock	17 0	48 0
Upper Estuarine Series.	Kale [*i.e.* hard shale]	2 0	50 0
	Soft rock	5 0	55 0
	Clay	17 0	72 0
	White kale	2 0	74 0
Lincolnshire Limestone.	Lincolnshire Oolite	104 0	178 0
Lower Estuarine Series.	"Lias"	20 0	198 0
Ironstone.	—Blue rock	17 9	215 9

SLEAFORD. (Sheet 70.)

Boring at the Great Northern Railway Station.

Communicated by MESSRS. LEGRAND and SUTCLIFF.

The water rose to 6½ feet above the surface and overflows at the rate of 20,000 gallons a minute.

		THICKNESS.	DEPTH.
		Ft. In.	Ft. In.
Soil.	—Clay	1 6	1 6
River Drift.	Sand	2 0	3 6
	Ballast	12 0	15 6
Great Oolite Limestone.	Soft stone	2 6	18 0
	Hard stone	4 0	22 0
Upper Estuarine Series.	Hard clay	8 0	30 0
	Stone	1 6	31 6
	Hard clay	16 6	48 0
Lincolnshire Limestone.	Stone rock (a sample sent is a grey oolitic limestone) ...	38 6	86 6
	Rock and layers of clay ...	2 6	89 0
	Rock oolitic	24 0	113 0
	Rock and thin layers of clay ...	4 0	117 0
	Rock	34 0	151 0

SLEAFORD. (Sheet 70.)

Boring at MESSRS. BASS & CO.'S Maltings.
Communicated by, with further information from, MESSRS. LEGRAND and SUTCLIFF, who deepened the boring from 113 feet.
Good spring at 156 feet which rose 13½ feet above the surface, with a flow of over 12,000 gallons an hour. On being deepened to 177 feet the bore yielded 30,000 gallons per hour.

		Thickness.	Depth.
		Ft. In.	Ft. In.
Surface Soil.	—Soil	1 6	1 6
Valley Gravel.	—Gravel and sand	12 0	13 6
Kellaways Beds.	—Clay	1 0	14 6
Cornbrash.	—Rock	10 0	24 6
Great Oolite Clay.	—Clay	24 0	48 6
Great Oolite Limestone.	Rock	12 0	60 6
Upper Estuarine Series.	Clay	7 0	67 6
	Rock	2 6	70 0
	Green clay	1 0	71 0
	Dark clay	4 0	75 0
Lincolnshire Limestone.	Rock	15 0	90 0
	Clay	2 9	92 9
	Hard grey rock	53 0	145 9
	Grey shelly rock	32 0	177 9

SLEAFORD. (Sheet 70.)

Well in the Cross Keys Yard.
Communicated by MR. JESSE CLARE, C.E., of Sleaford.

		Thickness.	Depth.
		Ft. In.	Ft. In.
Surface Deposits.	Made ground...	2 6	2 6
	Black peat	3 6	6 0
	Gravel and running sand ...	11 0	17 0
Great Oolite Clay.	Scaley rock	1 6	18 6
	Blue clay, hard and tough ...	4 6	23 0
Great Oolite Limestone.	Blue rock	11 0	34 0
Upper Estuarine Series.	Clay	9 0	43 0
	Rock	2 0	45 0
	Clay	25 0	70 0
Lincolnshire Limestone.	Rock with water	7 0	77 0
	Rock with more water	4 6	81 6

SWATON. (Sheet 70.)

Boring near MR. YARRAD'S premises, 1884–5.
Communicated by MR. JESSE CLARE, C.E., of Sleaford.
Water overflows all the year round, and is distributed through the village by gravitation.

		Thickness.		Depth.	
		Ft.	In.	Ft.	In.
Soil.	—Surface soil	1	0	1	0
Fen Gravel.	Yellow clay	3	6	4	6
	Wet gravel	2	0	6	6
	Wet running sand	1	6	8	0
Boulder Clay.	Dark blue clay with flint stones...	34	0	42	0
	Dark grey rock band (? a stone) ...	0	?	42	2
Oxford Clay and Kellaways Beds.	Light dry blue clay	57	10	100	0
	Hard blue rock	2	0	102	0
	Clay parting	0	6	102	6
? Cornbrash, 12⅓ feet.	Hard rock	7	0	109	6
	Clay parting	0	4	109	10
	Hard rock	5	0	114	10
Great Oolite Clay, 28½ feet.	Strong clay	4	0	118	10
	Very hard rock	0	6	119	4
	Strong clay	3	0	122	4
	Very hard blue clay	4	6	126	10
	Strong band	0	2	127	0
	Hard rock	3	6	130	6
	Strong band	2	0	132	6
	Rock	0	10	133	4
	Strong clay bands	10	0	143	4
Great Oolite Limestone, 21⅓ feet.	Rock with clay partings ...	5	4	148	8
	Hard rock	6	8	155	4
	Clay parting	0	3	155	7
	Very hard rock	9	1	164	8
Upper Estuarine Series, 27 feet.	Blue clay	1	6	166	2
	Rock	1	0	167	2
	Blue clay	4	6	171	8
	Rock	2	0	173	8
	Dark bands	7	6	181	2
	Rock	1	0	182	2
	Dark rock bands [? clay bands]...	4	6	186	8
	Rock	0	6	187	2
	Strong rock bands [? clay bands]	4	6	191	8
Lincolnshire Limestone.	Very hard blue rock	17	6	209	2
	Blue clay parting	0	6	209	8
	Very hard blue rock	30	6	240	2
	White rock	1	0	241	2
	Light grey rock parting ...	0	3	241	5
	Very hard rock	9	3	250	8

NORFOLK.

FAKENHAM. (Sheet 68.)

At MISS H. RUDGE'S, Wells Road, 1894.
Shaft 18 feet, the rest bored.

		THICKNESS.	DEPTH.
		Ft. In.	Ft. In.
Made soil		3 0	3 0
Glacial Drift.	Grey sand	15 0	18 0
	Quick sand	8 0	26 0
	Gravel	18 0	44 0
Chalk and flints		25 0	69 0

SAHAM TONEY. (Sheet 66, S.W.)

Boring at Broomley Hall, made by MESSRS. ADCOCK, and communicated by MR. F. W. HARMER, 1898.

		THICKNESS.	DEPTH.
		Ft.	Ft.
Glacial Gravel		20	20
Boulder Clay.	Blue clay	80	100
	Hard flints with clay	10	110
	Chalk and chalk marl	2	112
	Clay	35	147
Chalk.			

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Corrections to List in the Memoir on the Geology of the Country around Norwich.

1804. GRISENTHWAITE. Should not have been entered, not being geological.

1830-1833. SEDGWICK. Should have gone under 1826.

1839-40. WOOD. Should have been entered under 1840.

1858. TRIMMER. Should not have been entered. Gorleston is in Suffolk.

1859. CHARLESWORTH. Should not have been entered. Not Norfolk.

1862. ROSE. Should not have been entered. Refers to Suffolk, not to Norfolk.

1865. WOOD. Second entry. Should not have been entered. Only abstract of paper entered above (and the map is not entered).

1866. GUNN. First entry. Should have been under 1867.

1867. GUNN. Tenth entry. Should not have been entered. Corton and Hopton are in Suffolk.

1868. CHARLESWORTH. First two entries. Should not have been entered. Refer to Suffolk, not to Norfolk.

1868. CROWFOOT. Refer to Suffolk, not to Norfolk.

1868. GUNN. Fifth entry. Refer to Suffolk, not to Norfolk.

1873. GUNN. First entry. Refer to Suffolk, not to Norfolk.

1876. GUNN. Third entry. Refer to Suffolk, not to Norfolk.

1876. NORTON. Refer to Suffolk, not to Norfolk.

1877. BLAKE. Refer to Suffolk, not to Norfolk.

1878. BLAKE. Refer to Suffolk, not to Norfolk.

1878. SPALDING. Not geological. Should not have been entered.

1879. CROWFOOT. Should not have been entered. Beccles is in Suffolk.

1879. SKERTCHLY. First and last entries the same.

1880. HARMER. Should not have been entered. Corton is in Suffolk.

1881. PRESTWICH. First entry. Published in 1882.

1881. PRIGG. Published in 1882.

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